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Contents

The Geoff Brown Memorial Lecture 2001 1
Mechanisms and Consequences of Flood Basalt Volcanism
Professor Stephen Self, Department of Earth Sciences, The Open University

The Sandstone Quarries of Overton Hill, Frodsham : a Geological Study 6
Duncan Woodcock

From Genealogy to Geology 16
Gladys Dinnacombe

Beneath Our Feet : the geology of Islington; an explanation of how an exhibition in an urban environment was conceived, constructed and received 21
Diana Clements, BA (Open), Islington Museum and The Natural History Museum

Making thick " thin" sections - an update 29
Jane Clarke

Geo Walk - Perranporth to St Agnes 31
Mike Hermolle

A journey through Namibia 34
Elizabeth & David Maddocks

Patagonia Field Trip 2001 38
Anne Burgess, Mike Bell & Fred Owen

Branch reports 44

Book reviews 20,28,30,52

Constitution 54

Index to articles in the Open University Geological Society Journal to Spring 2002. Centre page pullout

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Cover illustration: Thin sections of several different habits of barite. Photographs: Jane Clarke.

Botryoidal barite Mag 538; ppl.	Acicular barite Mag 549; xpl.	Poikilotopic barite Mag 530; xpl.
Bladed barite (white) Mag 580; ppl.	Botryoidal barite Mag 538; xpl	Spherulitic barite Mag 584; xpl.
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The Geoff Brown Memorial Lecture 2001

Mechanisms and Consequences of Flood Basalt Volcanism

Professor Stephen Self, Department of Earth Sciences, The Open University

Introduction

I am honoured for this invitation to give the 2001 Geoff Brown Memorial Lecture. I knew Geoff, and his death was a great loss to our field.

In talking about the mechanisms and consequences of flood basalt volcanism; first I will explore how flood basalt lavas are erupted and emplaced; then discuss the 1783-84 Laki eruption in Iceland which I consider to be a modern analogue for flood basalt volcanism. This eruption produced a very nasty period of atmospheric disturbances in the Northern Hemisphere. Then I will consider a case study of a flood basalt lava flow from the Columbia River Basalt group in the north-western USA. We will examine what this flood basalt flow was like when it was being emplaced and what it might have produced in terms of atmospheric output. We shall end up looking briefly at the emplacement and the possible impacts of the Deccan flood basalt volcanism 65Ma ago, and I will draw some conclusions at the end.

My interest in flood basalts stems partly from the apparent synchronicity between the times that flood basalt provinces were formed and the major mass extinctions. Many of you must have heard about the current scientific discussions on the causes of mass extinctions. There is very good evidence to date for a meteorite impact at only one major mass extinction, the 65Ma Cretaceous-Tertiary boundary event, but also there was a flood basalt event occurring before, or a little after, that mass extinction occurred. But whichever way you want to argue it, out of eleven mass extinction events recognized in the past 300Ma, at least seven coincided with flood basalt volcanism (Figure 1). These are two totally different geological phenomena; they are both very short, lasting in the order of half a million to a million years. Tens of millions of years of geological time go by without either occurring, then suddenly these two events happen at the same time. Yet apparently they are not related? Mass extinctions are the dying out of a significant number of the genera on the surface of the earth whilst flood basalts are the result of mantle plumes derived from way down within the Earth erupting at the surface. One would not imagine there would be a connection but I think that the evidence is telling us something, as there are several of these apparent coincidences, not just one or two. Geologists are still working to refine the age dates but in almost every flood basalt – mass extinction "pair", as more age data is obtained, the closer the two events come together.

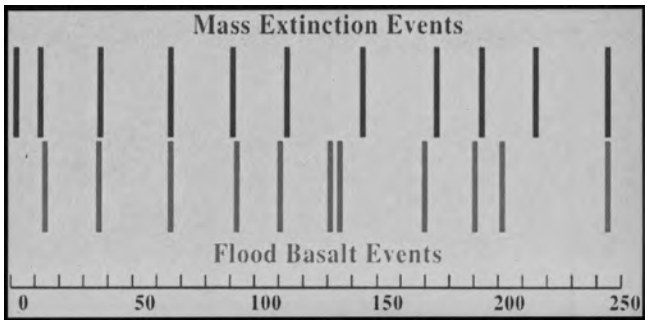

Figure 1. The best estimates of age dates for mass extinction events and the onset, or (where known) peaks, of flood basalt volcanism over the past 250Ma shown as time lines. Compiled from published data.

Figure 2. Cliffs at Dry Falls, Washington, USA, expose a section through three major flow fields of the Columbia River Basalt Group lavas. Uppermost is the Rosalia flow (> 2000km^3), middle is the Roza flow (1300km^3), and lowermost is the upper part of a Frenchman Springs member (volume ~ 2000km^3). The Roza flow field consists of two-three stacked, compound flows, up to 50m thick, at this location. Photo by S Self.

Flood basalt volcanism

What are, or were, flood basalts like? There is a lot of published information on the chemistry of flood basalts and where the magma originates in the mantle but there has not been much effort placed in interpreting the emplacement of flood basalt lava flows. What was it like when these huge volumes of lava were poured out onto the earth? These were events that caused, for example, the lava flows in Northern Ireland that host the Giant's Causeway, huge lava flows, much bigger than anything we have had on Earth in the last few millennia. One important fact is that during flood basalt events individual eruptions yield huge magma volumes, about 1,000 km^3. In comparison, Kilauea in Hawaii has poured out lava continuously for the last nineteen years and has only produced 1.5km^3! The Laki and Eldgja eruptions in Iceland, in 1783 and 934 AD, respectively, are the two largest lava outpourings on Earth in recent times. They both produced on the order of 15km^3 of lava, yet during the formation of a flood basalt province one eruption after another produces lava flows on the order of 1,000km^3. That is one significant difference with modern basaltic volcanism.

Flood basalt provinces are piles of vast lava flow fields and we define a flow field as the product of one eruption. When one examines a section in the Columbia River Basalt province, we see three large lava flows (Figure 2); one about 150m thick and two over 50m thick. Each of these is a section through a huge lava flow field, each of which, in turn, is made up of many flows.

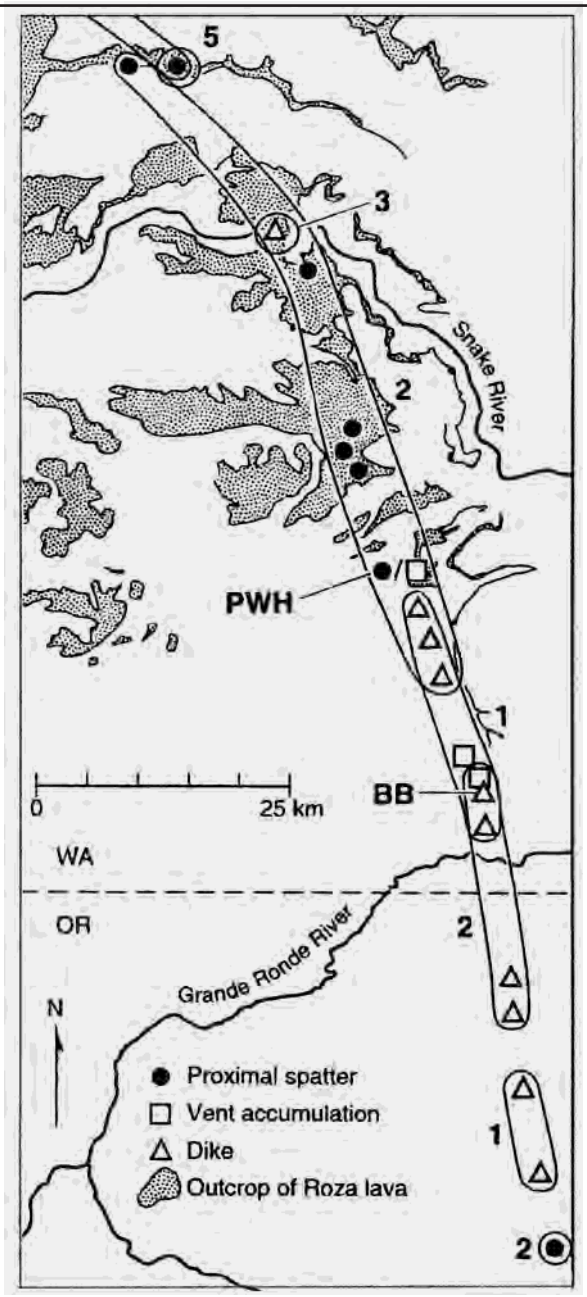

Figure 3. Map of the evidence for vent system that is thought to have fed the Roza lava flow field of the Columbia River Basalts. Compiled from published work by D A Swanson and B Martin, as shown.

These flow fields are dominated by pahoehoe lava, and sometimes slightly rubbly-topped pahoehoe sheet flows. Flood basalt flow fields are so huge and complicated that it is difficult to grasp the details of even one of these. They are composed of very extensive sheet lobes which do not seem to exist on such a scale other than in flood basalt fields. These bodies of lava have individual thicknesses of 50m and extend for many kilometres. One very rarely sees the contacts between sheet lobes in flood basalt fields, which gave the impression to the early workers that flood lava flows were single, simple, large sheets of lava up to 500km across.

Don Swanson of the United States Geological Survey worked in the Columbia River flood basalt province and discovered that the source vents for flow fields were long fissures. A map of the proposed point source vents, determined from spatter accumulations and dykes that produced the Roza lava flow field, illustrates this point (Figure 3). They lie along a 150km-long fissure. Flood basalt flow fields are thus not fed from a single point like a normal volcano, they are fed from a number of vents along a very long eruptive fissure. We suspect that during a flood basalt eruption innumerable vents produce lava, and that activity at many of these vents was also explosive, producing spatter and ash. We have also proposed that there were high fire-fountains.

Another important factor is that 50m-thick flood lava flows did not arrive at any point as a 50m-thick wall of liquid lava; that is a physical impossibility for the viscosity of lava that forms flood basalts. Such a wall of lava cannot be supported unless it is contained in a canyon that would constrain the lava from spreading out. They had to advance as little lobes, like we see in Hawaii and other places, and then gradually thicken by a process called inflation, or endogenous growth, and they gradually grow a thicker and thicker crust to attain a much greater thickness of lava in one flow. At the point of cessation of flow they had developed a thick crust on top whilst liquid lava was moving, or stagnating, underneath the crust. This is the key to getting very, very long lava flows; the crust is a highly effective insulator. Flood basalt flows advanced and covered the underlying lava flow on very, very flat plains; the average slope of the Columbia River field was about a tenth to a hundredth of a degree, so the flows were moving down a very gentle slope and were also able to spread out sideways.

One of the great mysteries of very long lava flows is the mechanism by which the liquid lava is transported hundreds of kilometres without freezing. There is only a 100° - 150°C dynamic range between the eruption temperature and the point that the liquid lava becomes solid. Thus during flow the lava can only cool by 100° to 150°C. This is now explained by the development of a thick crust as the flows are being emplaced. The liquid lava can move underneath the thick crust and looses only about 20°C while flowing through a series of sheet lobes over distances of hundreds of kilometres. In Hawaii, Kilauea fire fountains are often about 200m high and roughly 10ºC is lost in the fountains, then the lava enters a tube system through the lobes. The lava loses about 1°C per kilometre while travelling through the tubes, but for flood basalts that is not thermally efficient enough. Evidence requires them to lose no more than a few tenths of a degree Centigrade per kilometre. Eventually the lava must arrive at the flow front hundreds of kilometres from the fissure and emerge at only a few tens of degrees Centigrade cooler that at the vent, just like Hawaiian lavas, make new lobes, and gradually lengthen the flow field.

The Laki Analogue

Let us look at a fairly modern flood basalt analogue, the Laki eruption in Iceland, which took place in 1783 - 84. This is one of the two largest lava outpourings recognized on the Earth in the last few thousand years. The volume of magma erupted was 15km^3 and it was vented from the 25km-long Lakagigur fissure. Effusion spanned eight months but there was a period of peak output in the first two months, June and July of 1783. The average mass eruption rate was very large, about 1 x 10^6 kgs^{-1} during this peak period. Fire fountain heights were 600m to about 1.5km high, which may seem high but is perfectly plausible. Earlier this year (2001), Mount Etna produced a one-kilometre-high fire fountain for a few hours. The Laki fire fountains were sustained from various vents along the fissure and above these vent foun-

tains eruption columns rose to a maximum of about 13km high, and 7 to 9km on average. This is high enough for the eruption column, consisting of gas and small ash particles, to be injected through the troposphere and into the stratosphere. Surprisingly, the Laki ash fall amounts to the second biggest fall deposit from Iceland in the last 250 years.

The Laki lava event is typical of what we think flood basalt eruptions were like, but on a much smaller scale in all ways; a thin pahoehoe sheet was erupted in the first 40 days and then it was observed to thicken. The Icelandic people who witnessed the event reported in writing that they went to see the lava and it was only 1m or so thick, but when they returned many days later it was 15m thick in the same place. I think they were describing a flow that had thickened by inflation. We first of all thought they were just describing flows accumulating over each other and stacking up, but we now think that they were describing inflating pahoehoe sheet flows, because that is what forms much of the Laki flow field.

When volcanic gases rise into the atmosphere they form aerosols. These develop from the chlorine, fluorine, and, most importantly, sulphur gases released by the volcano. The volcanic ash has a very short residence time and falls out of the atmosphere very quickly. Much of the chlorine and fluorine ions are scrubbed out of the plume fairly quickly as they are very chemically dynamic; they quickly attach themselves onto the surfaces of water and ash particles. Sulphur, which is less chemically active and is usually released as sulphur dioxide, tends to stay aloft and combined with atmospheric water to form sulphuric acid droplets. These tiny particles of sulphuric acid are termed sulphate aerosols and they happen to form with a size range between about a 0.1 - 1μm, with a mean size of ~ 0.5μm. This is also the mean wavelength of the incoming radiation from the sun and so the aerosol particles are very good scatterers of incoming radiation. They act like a veil to block the sun's energy from reaching the Earth's surface and send it back out to space. When a volcanic eruption occurs, and sulphuric acid aerosols are formed, there is a net loss of radiation to the surface of the Earth and the surface cools. Concomitantly, these particles absorb radiation up in the stratosphere and the stratosphere becomes warmer than normal, but the net result is that the lower atmosphere and the surface cools. It has been noted many times that we experience cold and unusual weather after volcanic eruptions.

Large eruptions, like Laki, can produce a great deal of aerosols which have a dramatic effect. Figure 4 shows a map of the arrival dates of the Laki haze (or dry fog) as it moved from Iceland across Europe and Asia in June 1783. It very rapidly covered all of Europe and reached the Altai Mountains in Siberia by 1st July. It is known to have covered Japan, Alaska, and Hudson's Bay, spreading completely around the Northern Hemisphere in about a month. While the eruption continued there was dry fog reported everywhere. Effects of this dry fog included acid haze and precipitation which killed crops and pastures. In Iceland, the killing of the crops (and perhaps fluorine poisoning) caused death of most of the livestock and 25% of the population died. Widespread crop failure and famine was described from Ireland, Scotland, France and Switzerland, and there was increased mortality in the UK. John Grattan at the University of Wales has been looking at deaths in village census reports from this period throughout the British Isles and there is one period during the summer of 1783

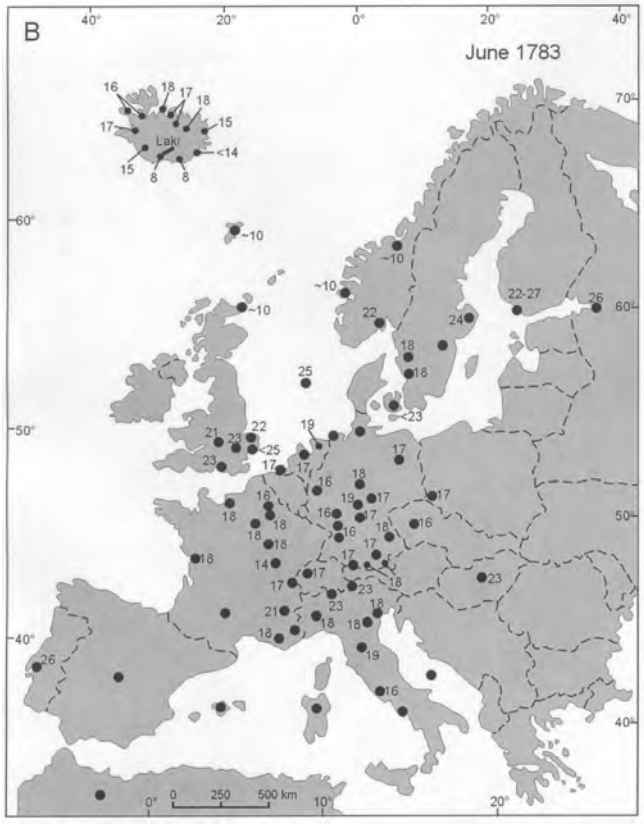

Figure 4. Map showing the locations and dates of the first occurrence of the Laki haze (dry fog) across Europe in June 1783. Dots without dates are locations where onset date is unspecified.

when the death rate in British villages rose 2 to 3 times. People were not generally very healthy back in those days and perhaps respiratory effects due to the gases and low-level aerosol cloud was enough to cause enhanced mortality? Strangely, the air temperature actually rose dramatically for a few weeks in parts of western Europe during the height of the eruption and that also led to crops withering and there was difficulty in keeping meat fresh. Then, for one year, it became extremely cold in Europe, and North America experienced the lowest winter temperatures ever recorded in north-eastern US. The Mississippi River was frozen at New Orleans and ice flows bobbed out into the Gulf of Mexico; the only time in recorded history that anything like this has happened.

By using geochemical microprobe analytical techniques on actual Laki lava and ash samples, we can measure the amounts of sulphur that the magma contained before and after eruption, and thus estimate the amount of sulphur dioxide that was emitted. Most of the gas from Laki, about 98 megatonnes (1Mt = 1×10^{12}gm) of SO_2 was released at the vents above the fissure, and about another 25Mt was released from the lava flow. The latter was the cause of the terrible conditions in Iceland as it circulated around Iceland and contributed to the low-level, local aerosols, or "haze", around the island. Another cloud travelled across the Atlantic and then subsided down over Europe and led to the more distant haze or dry fogs over Europe. These large amounts of gas were the cause the many environemental problems. Incidently, the average Laki peak output per month was equal to the total output of Mount Pinatubo in 1991. Pinatubo was the second largest eruption, and the biggest sulphate aerosol event, of the 20th century.

Case study of a flood basalt lava event

Now let us move on to flood basalt volcanism and consider the Roza flow, the most studied example of a flood basalt lava. The Roza flow field occupies an enormous area, about 40,000 km^2, and extends 300km from the vent system to the end of the flow. It was erupted about 15Ma ago in the Columbia River Province (which is now in Washington and Oregon in the northwestern US), and contains 1,300km^3 of tholeitic basalt in the one flow field. In Figure 2, there is a 2500km^3 flow sitting above it and another 2,000km^3 flow beneath it, each immense volumes of lava erupted in single events. The Roza lava flow field was formed in a piecemeal fashion, such that the lava was erupted in five bursts. Each of these formed a major lava flow, which is a highly complex group of flows and lobes in itself. These five major lava bodies are in juxtaposition, either on top of, or beside, each other.

My co-workers and I have been trying to determine how long it took to emplace the Roza flow. There has to be time for slow-moving pahoehoe flows to advance, inflate and then thicken, all the time gradually lengthening and widening the flow field. This mechanism does not preclude some of the individual flows being emplaced rapidly but we assess that up to 14 years of lava flow inflation is recorded at various locations. At these locations we see flows stacked on top of each other; lava arrived at one point and inflated and then another unit flowed over the top and inflated, and this process continued for at least 14 years. However, we cannot assess how long the hiatuses between the flows were, and thus estimates of total eruption duration still elude us. We know that the hiatuses were short enough for no sediment to accumulate or erosion to occur between the flows, and some of the flows are heat welded together, so we are assuming they are short (weeks to months?). Obviously, if there were time gaps of a year or two between each of the flows then the whole eruption duration would have been longer.

The Roza lava has been well preserved, so on this old flood basalt flow we can do the same type of geochemical analyses that we carried out on Laki lava. We obtained a sulphur budget for the eruption by analysing for the sulphur content of the erupted material in the dykes, at the vents, and in the lava flow. We can thus estimate how much sulphur was dissolved in the magma before it was erupted, as it was erupted, and then how much was left in the lava flow. By these measurements, we can estimate the amounts of sulphur released, as SO_2, and the amounts of aerosols that may have been generated. It is not surprising that with such enormous volumes of lava that the results suggest that staggeringly high amounts of sulphur dioxide could have been released. We have proposed that the Roza eruption would have released about 10,000Mt of SO_2 into the Earth's atmosphere. This could have formed 15,000Mt of aerosols during the entire eruption duration over which, if it lasted for ten years, about 1,000Mt of aerosols was entering the Earth's atmosphere every year for ten years; some of it into the stratosphere and some of it into the troposphere. The equivalent values for more recent eruption like Pinatubo are 20Mt, 200Mt from Tambora 1815 (the biggest eruption in historic times, which produced "the year without a summer") and a little less than 200Mt for Laki. Such a huge gas/aerosol event would amount to an environmental disaster from just one flood basalt eruption.

Bob Spicer (Open University) and other researchers who are interested in atmospheric and climate modelling have discussed the possible environmental impact of such an enormous gas event with me. Currently there are no computer models that will realistically handle huge amounts of sulphur gases and aerosols injected into the Earth's atmosphere over a period of several years to a decade. There has been no need to construct such models because we do not have flood basalt volcanism on Earth at the present time, and the situation is otherwise unprecedented. In the future, we will try to persuade some research groups to collaborate on what types of atmospheric phenomena, climatic change, and environmental impact such huge gas releases from flood basalt eruptions would generate.

Figure 5. A stack of pahoehoe sheet flows exposed in the Western Ghats near Mahabaleshwar, India. Each flow is approximately 20-30m thick. They are part of the Deccan flood basalt province and occur near the top of the lava pile. Photo by S Self.

Deccan flood basalt province

The most studied flood basalt event that accompanied a mass extinction at the Cretaceous-Tertiary boundary, 65Ma ago, produced the Deccan province in north-western peninsula India. Half of this large province is missing because it was rifted off during the development of the Indian Ocean and now rests on the ocean floor. The Indian plate segment was 25° to 30° south of the equator at that time, and India was beginning to move rapidly northwards to impact with Eurasia and create the Himalayas. From eruptions at that latitude there could be global dispersal of the aerosols and the gas. That is a very broad statement which may not be totally realistic because we are just beginning to develop climate models for the Earth's atmosphere 65Ma ago, that would allow us to make such predictions more accurately.

Work being done by Mike Widdowson and Simon Kelley at the Open University has produced some new Argon/Argon radiometric age dates for the Deccan lavas showing the age progression through the pile. They have shown that the time span between the oldest and youngest lavas is about 4Ma, but the most significant fact is the largest volumes were erupted within one, or perhaps two, short periods of time – perhaps less than half a million years (this has also been suggested by French researchers but without any controls on volume). The best age estimate for the mass extinction and the meteorite impact that caused the mass extinction sits right within this period of great lava outpouring in the Deccan. All flood basalt provinces that have been studied so far show a similar pattern; they begin with a trickle of lava and then there is a huge volume emitted in a short period of time, followed a dribble at the end. From the evidence we have to date, it appears that the meteorite impact, the mass extinction, and the main out-

pouring of the Deccan are all more-or-less synchronous. Therefore the Deccan eruptions were ongoing, and injecting gas and ash into the atmosphere at the time that the mass extinction occurred – this makes the situation very interesting.

There are several vital facts we would like to know about Deccan volcanism. In the field, we see enormous numbers of individual lava flows stacked up on top of each other, each an inflated pahoehoe sheet of more than 20m thickness (Figure 5), very similar to the kinds of flows that occurred in the Columbia River Province. What types of eruptions formed these flows, and how extensive are individual flow fields? At present there is no data on the total number of flow fields or eruptions that formed the Deccan, but we assume that such a big province was constructed by large numbers of eruptions. The minimum volume of the pile is about 750,000km^3 but will we be able to do similar sulphur budget calculations on Deccan flows that were done on the Roza and Laki flows? We assume that the Deccan flows were erupted in much the same style, however, unfortunately, we may not be able to analyse the lavas for sulphur. They have been exposed to an equatorial sub-aerial atmosphere for most of the 65Ma since they were formed and are very deeply weathered and chemically altered. This may have removed most of the original traces of volatile elements from the lavas. We also would like to know the lava volume/time relationships in even more detail than we know at present, which would enable us to estimate the sulphur dioxide production during the period of Deccan volcanism if we can find a way to measure the sulphur content of the lavas.

We may have to use proxies for the amounts of sulphur degassed and we might be able to achieve this by using other well studied examples, like Icelandic or Columbia River flows. The amount of sulphur that is contained in these flows is related to various other chemical parameters. By measuring these parameters (rather than the original sulphur) in inclusions in crystals (which represent the pre-eruption sulphur concentrations) and comparing this to the sulphur in the de-gassed lavas (which represent the post-eruption sulphur contents), we can obtain a crude estimate of the amount of sulphur degassed from these eruptions. If we can get reliable chemical analyses from the Deccan lavas and obtain ratios like the titanium:iron ratio, then we will be able to compare them with compositionally similar lava eruptions which are known to have degassed a certain amount of sulphur. This is the best hope we have at the moment of estimating the amounts of sulphur released by Deccan volcanism.

Another significant aspect of the Deccan province is the boles, which are soil layers between some of the lava flows that very infrequently contain fossilised plants and, sometimes, animals. Mike Widdowson has studied these soils and sediments and found that they also contain volcanic ash with a different chemical composition to the basaltic lavas. It appears that in between the eruptions of Deccan lavas there were also some explosive eruptions occurring as well. This was therefore a dynamic volcanic province with different types of activity going on. The boles may contain a record of explosive volcanism between the major basaltic eruptions, and then, in terms of gas release and atmospheric impact, the Deccan might have been a very active, fertile province in affecting the Earth's atmosphere by creating dense, extensive aerosol clouds.

Conclusions

So where should our research go from here? If we are going to examine the effects of flood basalts at times of mass extinction, we have a long way to go. We need to answer the questions that I mentioned previously about the Deccan flood province. We may eventually be able to estimate how much sulphur was released by flood basalt eruptions and the impact of the sulphate aerosols that would be generated on climate. After that we can address questions such as: What effect did these vast lava flow eruptions have on the biota at that time? Did they have a very deleterious effect on living organisms, both on land and in the sea, by affecting climate, by bombarding land surface environments with acid rainfall, and/or by affecting the most productive surface layers of the oceans and breaking down the food chain there? This seems to be a possibility, and it might be one way in which mass extinctions could occur. Every flood basalt province contains the products of not just one huge lava eruption but hundreds or thousands of great eruptions, each capable of creating an atmospheric environmental disaster, occurring time and time again during a very short period of geological time. Perhaps, cumulatively, these could produce a mass extinction, but we do not have the necessary evidence yet.

The formation of flood basalt provinces is a very interesting geological problem. Not only are flood basalts inherently interesting because they are such huge lava outpourings, we are beginning to understand how they were formed and that they may have had an effect on life on earth. Mass extinctions are the major occurrences within the evolutionary process on Earth. The 65Ma Cretaceous/Tertiary mass extinction knocked out 40% of all existing genera and about 75% of all species. The biggest one at 250Ma ago, which was coincident with the Siberian flood basalts, killed 70% of all genera and 95% of all species. These are major events in the evolution of life on Earth through which only selected species survive. Flood basalt eruptions could be implicated in extinctions by causing the biota to inhale noxious fumes and the effects of acid rain, as well as climatic impact, such as would be created in great abundance by the Deccan eruptions and other flood volcanism .

The Sandstone Quarries of Overton Hill, Frodsham : a Geological Study

Duncan Woodcock

Abstract

The fluvially dominated Lower Triassic sandstones, which crop out along the scarp of Overton Hill, Frodsham, Cheshire, were extensively quarried in the past. This study attempts to understand why one bed in particular was quarried, using a combination of field observations, particle size analysis and thin section examination to compare the features of the quarried bed with the beds immediately above and below. The quarried bed is *c.*5m thick and comprises subrounded to subangular grains with thin haematite rims which have allowed the development of quartz cementation by syntaxial overgrowth. In contrast, the adjacent beds are more thinly bedded and comprise more rounded grains with thick haematite rims that have inhibited quartz cementation; consequently these beds are much more friable. The quarried bed may have been deposited on a point bar in a deep river channel, while the adjacent beds were deposited in a mixed shallow fluvial-aeolian environment.

Introduction

Purpose of study

The solid geology of the Frodsham area comprises a suite of Triassic rocks of mixed aeolian and fluvial origin (Institute of Geological Sciences 1980). The spectacular aeolian sandstones have been described in the literature (Thompson 1969) and feature in a recent field guide (Eager and Broadhurst 1991). In contrast, the outcrops of fluvially dominated sandstones along the scarp of Overton Hill appear to have received much less attention despite extensive quarrying for building stones in the past. Quarrying appears to have been restricted to one bed of sandstone in particular. The purpose of the study is to attempt to understand why this particular bed, the Quarried Bed (QB), was the focus of the quarrymen's efforts.

The specific objectives of the study are:

i) to carry out a detailed field examination of the QB, together with the overlying and underlying beds, by means of large scale geological mapping and graphic logging of suitable sections;

ii) to compare the particle size distribution (PSD) of the QB with the PSDs of the beds immediately above and below;

iii) to study the texture and mineralogy of each of these three beds in hand specimen and in thin section.

Regional background

During the Triassic, NW Britain lay in the arid hinterland of the supercontinent of Pangaea (Anderton *et al.* 1983, Audley-Charles 1992). Subaerial conditions prevailed for much of the period, with deposition restricted to a number of fault-controlled basins. Palaeomagnetic studies indicated that NW Britain lay at a palaeolatitude of 10-20° north (Warrington & Ivimey-Cook 1992), a latitude characterised today by easterly winds and a number of hot deserts.

Much of the Triassic period is characterised by the deposition of continental red beds. In the early Triassic, the newly uplifted Hercynian massifs provided coarse sediments that were transported by north-flowing rivers during flash floods and deposited as fining upward cycles of pebbles and cross bedded sandstones. Background sedimentation comprised finer grained sands and silts deposited in the beds of river systems. These predominantly arenaceous sediments comprise the Sherwood Sandstone Group (Ruffell & Shelton 1999). In the mid Triassic, a temporary marine transgression brought a "whiff of the sea" (Anderton *et al.* 1983) and allowed limited deposition under marine conditions. Subaerial, arid conditions returned, allowing deposition of evaporitic mudstones in a playa lake environment. The mid Triassic sediments are thus predominantly argillaceous and comprise the Mercia Mudstone Group (Ruffell & Shelton 1999). In the late Triassic (Rhaetic) a marine transgression progressively replaced continental red beds by marine shales and silts of the Penarth Group.

The Cheshire Basin is one of a number of Permo-Triassic basins in NW Britain. Basin formation began in the early Permian and by the early Jurassic had accumulated up to 4km of sediment. The basin comprises a faulted half graben, in which basin subsidence

Table 1. Permo-Triassic stratigraphy of the Cheshire Basin.

Period	Stage	Group	New Nomenclature		Old Nomenclature 1860 - 1980		Thickness/ m	Palaeoenvironment
Jurassic			Lower & Middle Lias				700	shallow marine
Triassic	Rhaetic	Penarth	(undivided)		Rhaetic Beds		10	shallow marine, evaporitic
	Norian	Mercia Mudstone Group	Blue Anchor Fm.		Tea Green Marls	Keuper	20	hypersaline lagoon, continental
			Brooks Mills Mudstone Fm		Upper Keuper Marl		150	hypersaline lagoon, continental
	Carnian		Wilkesley Halite Fm		Upper Keuper Saliferous Beds		250	arid and saline, marine feed
	Ladinian		Wych Mudstone Fm.		Middle Keuper Marl		100	hypersaline lagoon, continental
			Byley Mudstone Fm.				100	
	Anisian		Northwich Halite Fm.		Lower Keuper Saliferous Beds		100	arid and saline, marine feed
			Bollin Mudstone Fm		Lower Keuper Marl		200	hypersaline lagoon, continental
			Tarporley Siltstone Fm		Keuper Waterstones		150	fluvial to marine
		Sherwood Sandstone Group	Helsby Sandstone Fm	Frodsham Member	Lower Keuper Sandstones		150	predominantly aeolian
				Delamere Member				fluvial, low sinuosity
				Thurstaston Member				mixed aeolian-fluvial
	Scythian		Wilmslow Sandstone Fm.		Bunter Upper Mottled Sandstone	Bunter	700	mixed aeolian-fluvial
			Chester Pebble Bed Fm		Bunter Pebble Beds		100	fluvial , low sinuosity
Permian			Kinnerton Sandstone Fm		Bunter Lower Mottled Sandstone		500	aeolian
			Manchester Marl Fm					marine/intertidal
			Collyhurst Sandstone Fm.					aeolian

was controlled by movement along the Red Rock-Wem Fault (Colter & Barr 1975). The Permian to Middle Lias basin fill was subsequently covered by an estimated 2km of post-Middle Lias sediments (Evans *et al.* 1993). The stratigraphy of the basin fill is presented in Table 1 (based on Eager & Broadhurst 1991, Evans *et al*. 1993). Lithofacies units are probably diachronous; the lack of diagnostic fossils makes correlation with time stratigraphic stages somewhat tenuous (Colter & Barr 1975). A detailed stratigraphy of the Helsby Sandstone Formation (Lower Keuper Sandstones) is presented in Thompson (1970).

Previous work done in study area

David Thompson (Thompson 1966) makes passing reference to exposures on Overton Hill in his monumental MSc thesis.

There is no modern BGS memoir that includes the area studied, although Memoir 109 (Earp & Taylor 1986) covers similar rocks in the Helsby area, about 3km to the south. An older Geological Survey memoir (Hull 1865) makes reference to the range of hills in the Frodsham area, the crests of which mark the junction between the Bunter and Keuper Sandstones. A later edition of the same memoir (Hull 1882) contains some specific references to exposures in Dunsdale Hollow on Overton Hill, where the author recorded the following stratigraphy:

"Keuper: Brown conglomeratic sandstone 18 feet
Conglomerate of lumps of marl 0 to $^1/_2$ foot
Grey seam $^1/_2$ foot
Bunter: Soft, red & white current-bedded sandstone 36 feet"

The QB crops out along the crest of Dunsdale Hollow, where it can be identified with Hull's "brown conglomeratic sandstone". It thus appears that the QB is included within the Helsby Sandstone Formation immediately above the boundary with the Wilmslow Sandstone Formation.

Methods & Materials

Geological mapping

The exposures of the sandstone along the top of the scarp slope of Overton Hill were studied in detail and the location of significant features recorded on the base map. Particular attention was given to the location of the top and bottom of the QB. Graphic logs were drawn at five locations where the QB is particularly well exposed.

Field sampling

Bulk field samples of between 0.25kg and 1kg , depending on grain size, were collected. Most samples were collected from locations along graphic log traverses, in which case the location of each sample was accurately recorded on a graphic log. Sample size was such that a coarse, non-flaggy sample came from a stratigraphic width of 5-10cm, while a finer grained, flaggy sample could be constrained to a stratigraphic width of 1-2 cm. These bulk field samples were used to produce hand specimens, to provide material for PSD analysis by sieving and for thin section preparation.

Measurement of particle size distribution (PSD)

Almost all samples were sufficiently friable to allow the PSD of disaggregated samples to be determined by sieving, using a set of six standard 8" sieves ranging in mesh size from 850μm to 45μm.

There is a variety of advice on sample size and sieving time in the literature (Lewis & McConchie 1994, Ingram 1971). In view of this often conflicting advice, a preliminary set of sieving experiments was carried out to help establish a standard procedure.

The key conclusions were:

i) The use of "cone and quarter" to split samples of the required size out of a larger disaggregated sample introduced significant error: it was preferable to disaggregate a sample of the size required.

ii) The measured PSD was relatively insensitive to sieving times greater than about five minutes; a sieving time of ten minutes was chosen for the standard procedure.

iii) The measured PSD was relatively insensitive to sample size; for the standard procedure, sample sizes were chosen in accordance with the following table:

grain size (visual comparison with grain size chart)	fine sand	medium sand	coarse sand
sample size chosen for PSD/g	50	70	90

Individual sieved fractions were weighed to the nearest 0.1g on an electronic balance. In all cases the total weight of the size fractions recovered was compared with the original sample weight and results were discarded if the difference was greater than 0.5%.

For each run the weight % for each size fraction collected was calculated. A plot of cumulative weight % against logarithm of sieve size (ϕ) on arithmetic probability paper provides a convenient graphical summary of the measured PSD. Figure 1 shows an example plot. An alternative way of summarising the PSD is to calculate the various statistical parameters of mean, standard

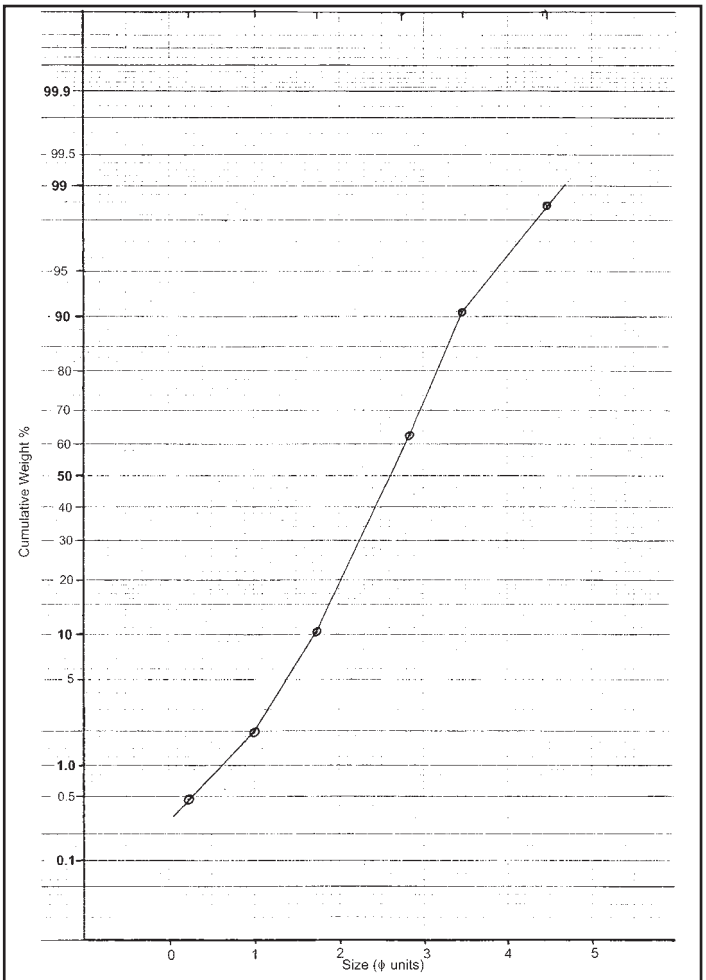

Figure 1. Cumulative wt% vs size: Sample H

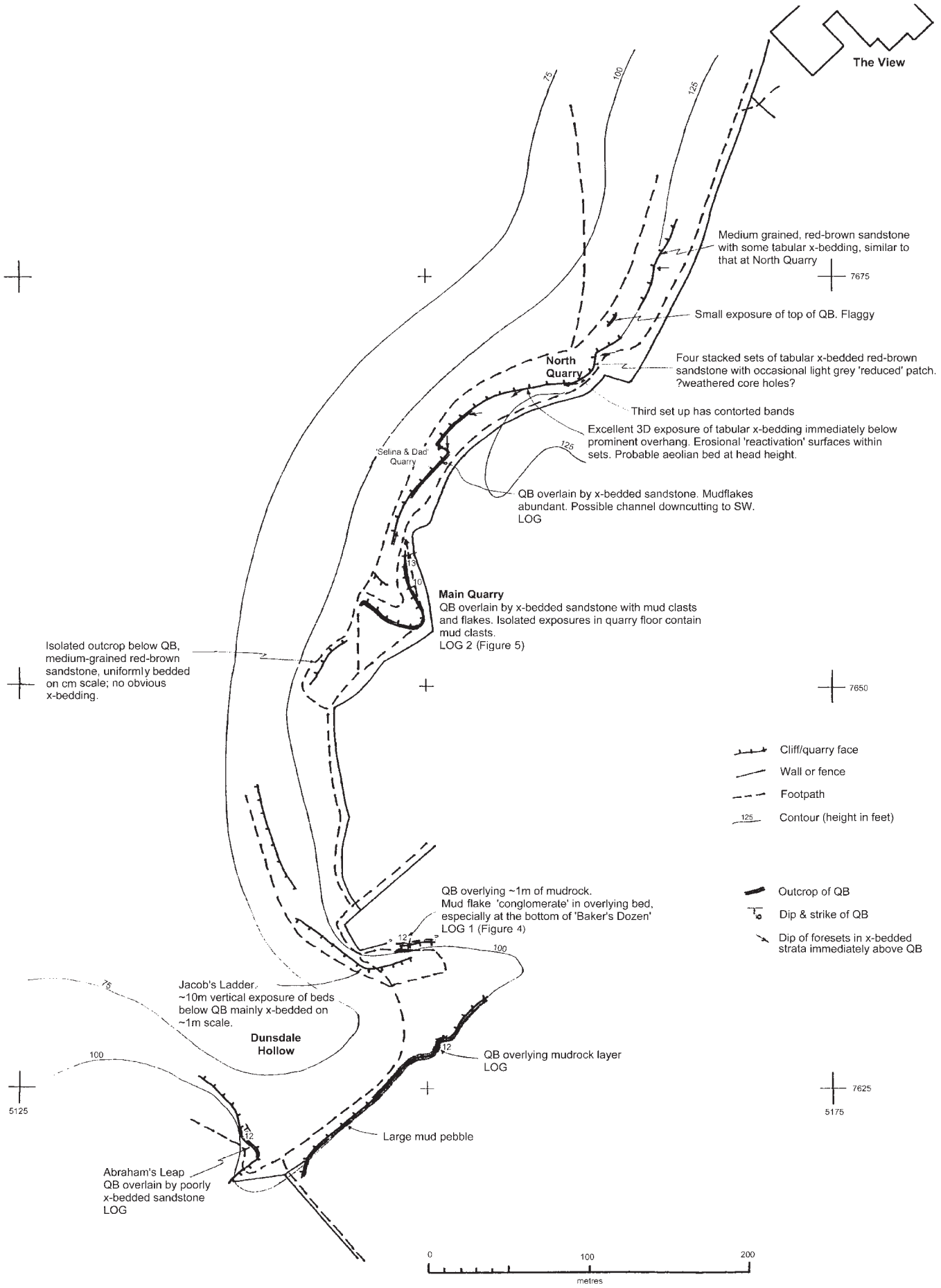
The View
Medium grained, red-brown sandstone with some tabular x-bedding, similar to that at North Quarry
7675
Small exposure of top of QB. Flaggy
North Quarry
Four stacked sets of tabular x-bedded red-brown sandstone with occasional light grey 'reduced' patch. ?weathered core holes?
Third set up has contorted bands
Excellent 3D exposure of tabular x-bedding immediately below prominent overhang. Erosional 'reactivation' surfaces within sets. Probable aeolian bed at head height.
'Selina & Dad' Quarry
QB overlain by x-bedded sandstone. Mudflakes abundant. Possible channel downcutting to SW.
LOG
Main Quarry
QB overlain by x-bedded sandstone with mud clasts and flakes. Isolated exposures in quarry floor contain mud clasts.
LOG 2 (Figure 5)
Isolated outcrop below QB, medium-grained red-brown sandstone, uniformly bedded on cm scale; no obvious x-bedding.
7650
Cliff/quarry face
Wall or fence
Footpath
Contour (height in feet)
Outcrop of QB
Dip & strike of QB
Dip of foresets in x-bedded strata immediately above QB
QB overlying ~1m of mudrock.
Mud flake 'conglomerate' in overlying bed, especially at the bottom of 'Baker's Dozen'
LOG 1 (Figure 4)
Jacob's Ladder.
~10m vertical exposure of beds below QB mainly x-bedded on ~1m scale.
Dunsdale Hollow
QB overlying mudrock layer
LOG
5125
7625
5175
Large mud pebble
Abraham's Leap
QB overlain by poorly x-bedded sandstone
LOG
0
100
200
metres

Figure 2. Geological map of the Sandstone Quarries of Overton Hill at Frodsham.

deviation, skewness and kurtosis. Kurtosis is seldom used by sedimentologists (Tucker 1981, Pettijohn *et al.* 1987) and its accurate determination requires PSD measurements to a resolution of 0.25 to 0.5ϕ (Folk 1966), so it was not considered further in this study. The mean, standard deviation and skewness were calculated both by the Method of Moments (Tucker 1981) and by using the formulae of Folk and Ward (1957).

Production and examination of rock thin sections

All samples were friable to some extent and needed stabilising before they could be ground to 30μm, or in some cases even sliced. Stabilisation was successfully carried out by repeated immersion in a *c.*2% solution of Araldite slow setting adhesive in acetone. Slices 3-4mm thick were carefully cut from the bulk field samples so that the plane of the slice was at right angles to the plane of any bedding/lamination visible in the sample. They were then repeatedly immersed in the Araldite solution once or twice a day until no further bubbles of air were observed to escape from the slices: at this point, any voidage was presumed full of Araldite. The slices were then left at room temperature for a week to allow the Araldite to harden. One surface of each slice was then ground flat with 220 mesh silicon carbide grit, thoroughly cleaned and dried and then repeatedly reimmersed in the Araldite solution until no bubbles were observed. Slices were then allowed to harden for a further week, followed by a few hours at 60°C. It was then possible to regrind a flat surface with 220 grit followed by 600 grit without any grain pullout. The slice was then mounted on a microscope slide with Lakeside 70°C thermoplastic cement, ground to a thickness of 30μm, trimmed and then a cover slip added with Canada Balsam cement. No attempt was made to transfer the 30μm slice to a clean microscope slide. See Woodcock (1993) for the detailed procedure used.

A total of 26 thin sections were prepared, all without grain pullout, and studied with a standard petrological microscope. An estimate of the modal compositions for a selection of the thin sections was made by point counting. Following the advice of Galehouse (1971), about 300 points were counted per thin section. It was impractical to etch the thin sections with HF and then stain to allow easy identification of untwinned alkali feldspar (Deer *et al.* 1985), consequently the counts for feldspar are expected to be low.

Results

Geological map

A geological map of the study area is presented in Figure 2. There is almost continuous exposure from North Quarry down to Main Quarry, where the QB is well exposed together with the contact with the overlying beds. Further south, the QB crops out on both sides of Dunsdale Hollow, where the contact with the underlying beds is well exposed.

Geological descriptions & graphic logs

Several graphic logs were drawn up to record the details of the QB at well exposed locations, as well as the beds exposed above and below. Two sample logs are presented in Figures 4 and 5. Descriptions for additional well exposed locations are as follows:

a) Beds above QB

These beds are particularly well exposed in North Quarry at GR SJ516767 and in the cliff faces immediately to the south. The sandstone is medium grained, friable and reddish-brown, although there are small patches of paler sandstone. Figure 3 is a sketch of the exposure in the NE end of the quarry. The exposure comprises four sets of cross beds, each about 1m thick and separated from each other by subhorizontal erosional bounding surfaces. The foresets are slightly concave up, in general with tangential contact with the lower bounding surface. In some places, such as at the top of the second set up, there are local erosion surfaces. Cross bedding in the third set up becomes increasingly irregular as it is traced SW, where close examination reveals small folds in some foresets. This folding is localised in one bed and is not present in the beds above and below, suggesting a syndepositional rather than a tectonic origin.

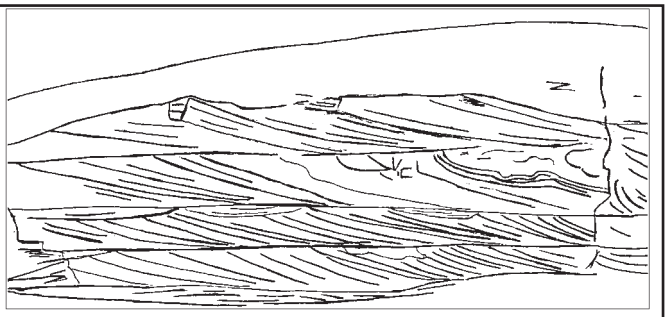

Figure 3. NE end of North Quarry (face *c.*5m high).

b) Beds below QB

These beds are well exposed at Jacob's Ladder, where about 10m vertical thickness of friable reddish-brown sandstone is exposed in cross bedded sets of 0.5 to 1.5m thickness. In general it is medium grained, but there are occasional lenses of coarser sandstone with well rounded grains.

Particle size distribution

The range of Folk and Ward parameters for the samples collected in the study area are:

- means range from 0.97ϕ to 3.23ϕ (medium sand to very fine sand)
- standard deviations range from 0.29ϕ to 0.86ϕ (very well sorted to medium sorted)
- skewnesses range from -0.14ϕ to 0.57ϕ (nearly symmetrical to strongly fine skewed).

The Folk and Ward PSD parameters have been added to the summary graphic logs, where the data can be viewed in the context of the field data.

Petrography

A total of 26 thin sections were examined, along with the corresponding hand specimens. A summary of the key observations is presented in Table 2. From an examination of this summary table it is possible to group most samples into three types, which are described in detail below.

Type 1: Beds above and below QB

These sandstones are reddish-brown, medium grained and well sorted. In hand specimen they tend to be quite friable. In thin section the grains are mainly rounded to subrounded and are predominantly in point contact with each other. Most grains have relatively thick rims of a red-brown material (?haematite) which is not significantly thinned at grain contacts. Blebs of this material sometimes occupy some of the porosity. The grains are predominantly quartz, both monocrystalline and polycrystalline.

Table 2. Summary of petrographic observations.

HS Ref	TS Ref	Grain Size	Sorting	Grain Shape	Haematite Rims	Syntaxial o/grow	Abundances				Log No.	Location wrt QB	Type		
							F/spar	Biotite	Musc	H/min			1	2	3
45	N31	medium	mod	subrounded	some	rare	none	some	some	common		above	*		
E	N20	medium	well	rounded	all,thick	rare	none	none	none	rare		above	*		
57	N26	medium	poor	subrounded	none	?	some	none	some	common		top			
D	N19	fine	mod	subangular	all	common	some	none	some	common		top			*
A	N17	fine	mod	subangular	all	common	rare	some	some	some		mid			*
B	N16	fine	mod	subrounded	all	common	rare	none	none	none		mid		*	
C	N18	medium	well	subrounded	all	common	some	none	rare	some		base		*	
14	N41	fine	mod	subangular	all	common	rare	some	some	rare	1	top			
13	N40	fine	mod	subangular	all	common	rare	some	some	rare	1	mid			
10	N28	medium	mod	subrounded	all	none	rare	none	rare	rare	1	base		*	
44	N42	very fine	mod	subangular	none	?	rare	common	common	common	1	below			
55	N44	medium	v. well	rounded	all,thick	rare	rare	none	none	none		above	*		
54	N43	medium	well	rounded	all,thick	rare	rare	none	none	rare		above	*		
95/5	N14	medium	mod	subrounded	all	common	some	rare	rare	rare	2	above	*		
Q	N30	medium	mod	subrounded	all	common	rare	none	none	rare	2	above	*		
20	N29	fine	mod	subangular	none	?	rare	common	common	common	2	top			*
19	N24	v. fine	mod	subangular	all	rare	rare	common	common	common	2	top			*
18	N27	fine	mod	subangular	all	common	rare	common	common	common	2	top			*
I	N21	fine	mod	subangular	some	common	rare	common	common	common	2	top			*
K	N22	medium	well	subrounded	all	common	some	rare	rare	rare	2	mid		*	
M	N25	medium	mod	subrounded	some	common	rare	none	rare	rare	2	mid		*	
32	N15	medium	well	subrounded	all	common	some	none	rare	some	2	mid		*	
17	N23	medium	well	rounded	all	common	rare	rare	none	rare	2	base		*	
G	N47	medium	mod	subrounded	all,thick	none	rare	none	rare	rare		above	*		
Y	N46	medium	well	subrounded	all,thick	none	rare	none	rare	none		above	*		
Z	N48	medium	well	rounded	all,thick	some	rare	none	none	rare		below	*		

Syntaxial overgrowths are rare; if present they occur only on monocrystalline grains with a relatively thin red-brown rim. Monocrystalline grains display a variety of extinctions in XPL, from unit extinction, through varying degrees of undulose extinction, to grains with strain bands. Polycrystalline quartz grains display a variety of sizes of individual crystals (subgrains) with boundaries that are predominantly sutured. Feldspar grains are uncommon, although a variety of types, including microcline, plagioclase and perthites, are present. Micas are rare or absent in most of these thin sections. Small rounded grains of heavy minerals, principally zircon, tourmaline and an opaque mineral occur occasionally in most thin sections, the grains usually being smaller than the surrounding quartz grains. All thin sections in this group contain a number of rock fragments; these include fragmental grains of a finer grained sandstone or grains of mudstone together with a variety of crystalline rock fragments.

Type 2: Lower QB

In hand specimen, these rocks tend to be a lighter reddish brown and less friable than Type 1. In thin section, they are similar to Type 1, but with a tendency towards subangular grains with much thinner red-brown rims. Syntaxial overgrowths are very common on monocrystalline grains, where they often form significant bridges between adjacent quartz grains. When present, any undulatory extinction in the original grain extends into the syntaxial overgrowth. Syntaxial overgrowths are rare on polycrystalline grains, being restricted to grains with a few subgrains.

Table 3. Average modal analysis for Type 1 & 2 samples.

	Type 1 (above & below QB)		Type 2 (lower QB)	
	Overall	Haematite & porosity free	Overall	Haematite & porosity free
Monocrystalline quartz	50	62	53	63
Polycrystalline quartz	25	31	24	28
Feldspar	0.5	1	0.5	1
Rock fragments	5	6	7	8
Haematite	3.5		4	
Porosity	16		11.5	
Total	100	100	100	100
% total quartz		93		91
Classification	sublitharenite		sublitharenite	

Type 3: Upper QB

In hand specimen, these rocks are fine grained with a flaggy tendency. Mica grains are visible on fresh split surfaces. In thin section these moderately sorted sandstones often show a millimetre scale lamination due to an alternation of fine and coarse grains. The grains are mainly subangular and predominantly in point contact with each other. Most grains have thin rims of red-brown material. The grains are mainly quartz, with a marked predominance of monocrystalline grains over polycrystalline grains. Syntaxial overgrowths are common on monocrystalline grains. Feldspar grains are uncommon. Micas are much more common than in the other two types and grains are often deformed by bending across adjacent grains or by splaying of grain ends. Muscovite is more common than biotite; the latter is relatively unaltered, clearly displaying a characteristic light-dark pleochroism. Heavy mineral grains are much more common than in the other two types, although this may be due to the overall finer grain size. In addition to zircon, tourmaline and opaque grains, a few grains of sphene, rutile and apatite are present.

Discussion

Graphic logs

Graphic logs were found to be a useful way of summarising a range of data; several aspects are worth further comment.

The QB is invariably fining upwards, from a medium grained sandstone at the base to a fine grained flaggy micaceous sandstone at the top; it may have been produced by lateral accretion on a point bar (Walker & Cant 1986). The beds immediately above and below the QB often contain tabular cross bedding. These beds may have been produced by the downstream migration of transverse bars, a characteristic of sandy braided rivers. (Collinson 1986, Turner 1980).

Mudstones are present at several localities, principally at the top of the QB or immediately below the base of the QB. These suspension deposits are laterally impersistent: the prominent mud-

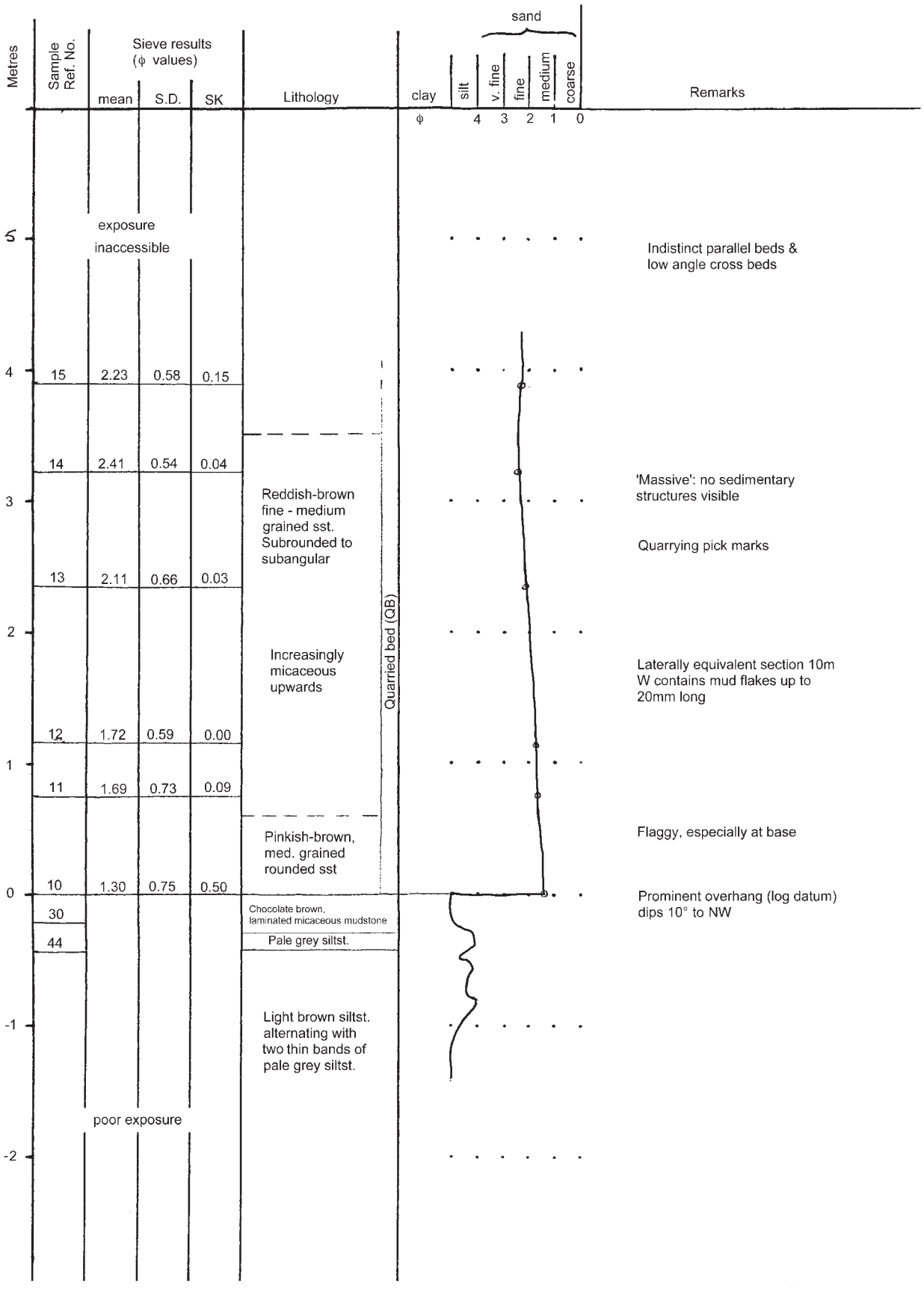

Figure 4. LOG 1. Location: North side of Dunsdale Hollow. Grid Ref. SJ 5150 7634.

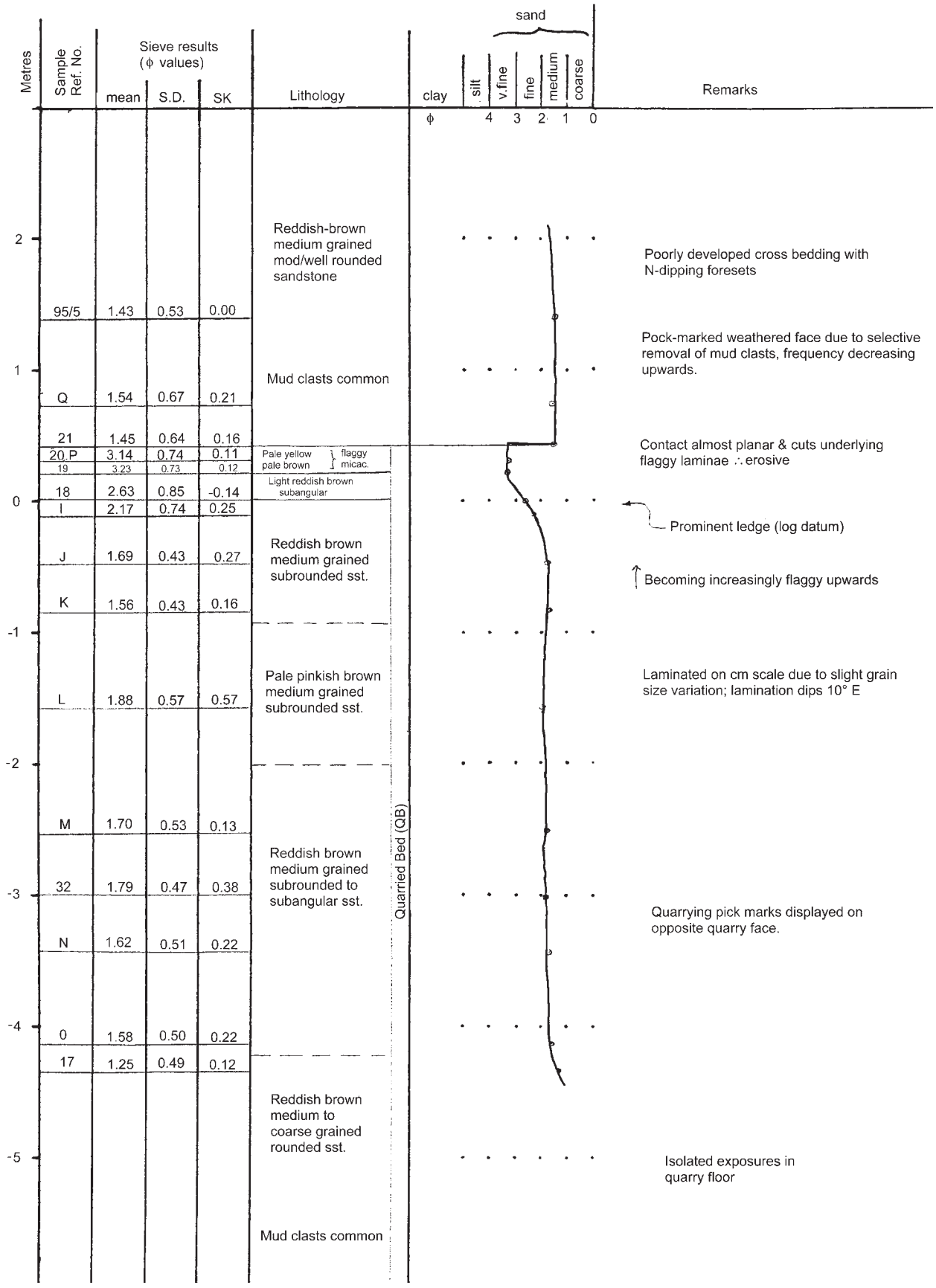

Figure 5. LOG 2. Location: NE Face of the Main Quarry. Grid Ref. SJ 5150 7655 (below ledge) - 5149 7658 (above ledge).

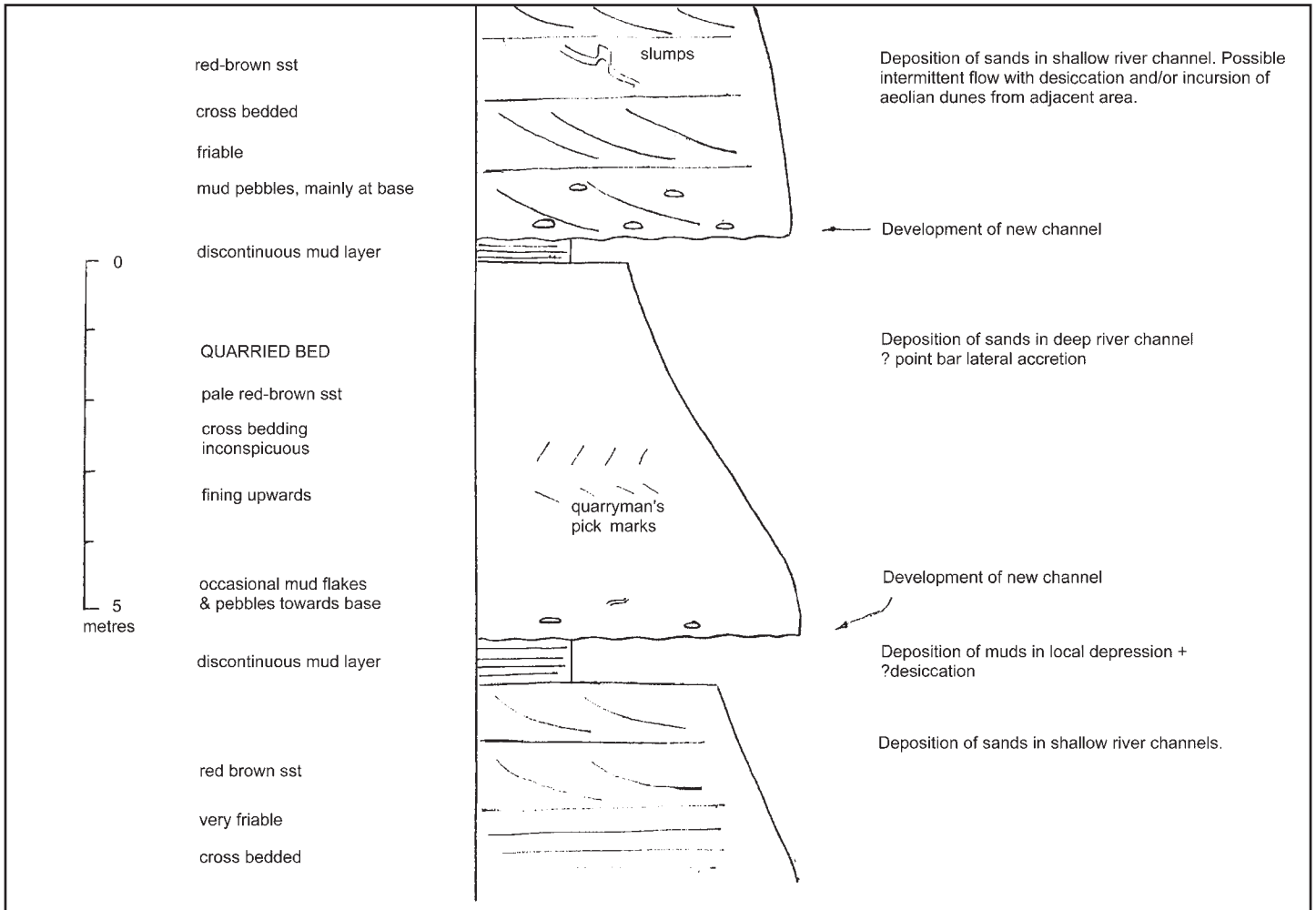
red-brown sst
cross bedded
friable
mud pebbles, mainly at base
discontinuous mud layer
0
QUARRIED BED
pale red-brown sst
cross bedding inconspicuous
fining upwards
occasional mud flakes & pebbles towards base
5
metres
discontinuous mud layer
red brown sst
very friable
cross bedded
slumps
quarryman's pick marks
Deposition of sands in shallow river channel. Possible intermittent flow with desiccation and/or incursion of aeolian dunes from adjacent area.
Development of new channel
Deposition of sands in deep river channel ? point bar lateral accretion
Development of new channel
Deposition of muds in local depression + ?desiccation
Deposition of sands in shallow river channels.

Figure 6. Composite graphic log for the sandstones in the quarries at Overton Hill, Frodsham.

stone band in Log 1 (Figure 4) cannot be traced to the east for more than ten metres. The mudstone deposits probably represent deposition in small local depressions in the palaeosurface during periods of low water level in a fluvial environment.

In some logs (e.g. Log 2, Figure 5), a mudstone layer is absent at the top of the QB and the overlying beds lie directly on the flaggy beds of the QB. Careful examination of the contact shows that in places it cuts the underlying flaggy laminae and is thus erosive. The overlying beds invariably contain mud flakes and pebbles with an abundance that decreases upwards from the contact. It may be that any mudstone layer originally deposited at these locations has been eroded to form mud flakes and pebbles. It is unlikely that these flakes and pebbles were eroded directly from a mud layer. A possible mechanism (Leeder 1999) involves desiccation of a relatively thin mud layer to form mud cracks and curls, followed by flooding and incorporation of the mud fragments into the sandy bed load of the river. This model is consistent with a climate characterised by distinct wet and dry periods.

Within the beds above the QB beds occasionally occur that are distinguished by steeper than normal foresets and extreme friability. In hand specimen, these can be seen to comprise very well rounded grains and to be very well sorted. These features suggest some aeolian influence (Thompson 1966), either the incursion of a local sand dune into the river system during a dry period (Herries 1993) or aeolian reworking of an exposed river channel bar (Leeder 1999). They provide additional evidence for an arid or semiarid palaeoclimate.

The thickness of the QB (*c.* 5m) contrasts with the typical thickness of *c.*1m for a cross bedded set above and below the QB. On the assumption that bed thickness correlates with river channel depth (Allen 1965), the depositional environment of the QB must be significantly different from that of the beds above and below: perhaps a deeper meandering river channel encroached on an area that previously and subsequently was dominated by a network of smaller, shallower braided channels.

Figure 6 is an attempt to produce a composite graphic log in which local variation is "distilled out" and the "essence" retained (Walker 1986). The resulting local palaeoenvironment is a microcosm of a much larger palaeoenvironment in the Cheshire Basin during the early Triassic.

Particle size distribution

The measured PSD parameters of mean, standard deviation and skewness have been added to the relevant graphic logs. The mean particle size decreases systematically upwards within the QB but shows no systematic variation elsewhere at the scale of sampling. Standard deviation is a measure of sorting and these data are useful in confirming the very well sorted nature of certain beds with possible aeolian affinities. Almost all samples have a positive skewness, which is characteristic of both aeolian and fluvial modern day environments (Friedman 1979).

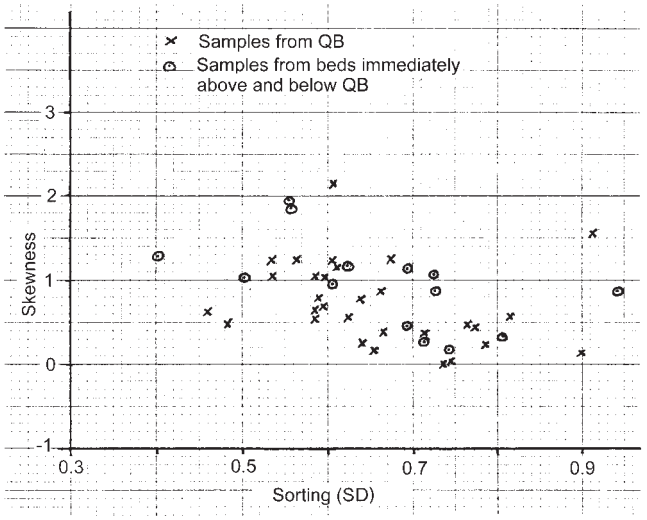

Figure 7. Scatterplot of skewness vs. sorting.

Friedman (1979) has used scatterplot of skewness vs. sorting (SD) to discriminate between modern day aeolian and fluvial sands, where aeolian sands were seen to be significantly more skewed. Figure 7 shows a similar plot for all the samples from this study. There appears to be little distinction between the QB and the beds above and below. In retrospect, the considerable effort spent in carrying out the PSD analyses has produced little return. This is in accord with the experience of many sedimentologists (Pettijohn 1975).

Petrography

Samples from above and below the QB, together with samples from the lower QB, are sublitharenites and there is no significant difference in modal analysis between these two types of samples. Samples from the upper QB are quartz arenites. All samples are both compositionally and texturally mature as might be expected from a continental fluvial environment. Some of the larger grains are well rounded and may be inherited from an aeolian environment (Kuenen 1960).

The key petrographic observations are concerned with grain shape and with the development of syntaxial overgrowths on quartz grains. Figure 8 summarises the model. The principal control is the thickness of the haematite rims on the quartz grains: thin rims allow some degree of quartz cementation by syntaxial overgrowth, while thick rims inhibit overgrowths – in this case the sandstone is weakly cemented by haematite. A secondary control is grain shape: subangular grains tend to give a stronger, less friable sandstone than those comprising more rounded grains.

Synthesis

The QB is characterised by a relatively thick bed, subrounded to subangular grains and thin haematite rims which allowed the development of some degree of quartz cementation. These three characteristics combine to produce a sandstone which is suitable as a building stone and was thus extensively quarried. In contrast, the beds above and below the QB are thinner, have more rounded grains and thick rims of haematite which inhibited quartz cementation: they are too friable for use as building stones.

The overall control appears to be the depositional environment: the QB was probably deposited within a relatively deep river channel, while the beds above and below were probably deposited in a mixed shallow fluvial-aeolian environment. This difference in depositional environment immediately explains the differences in bed thickness and grain shape, but does not immediately provide an explanation for the variation in the thickness of the haematite rims. Perhaps thick haematite rims are developed best in an environment subjected to periodic flooding and desiccation, when haematite precursors become concentrated on grain surfaces. This is a topic for further research.

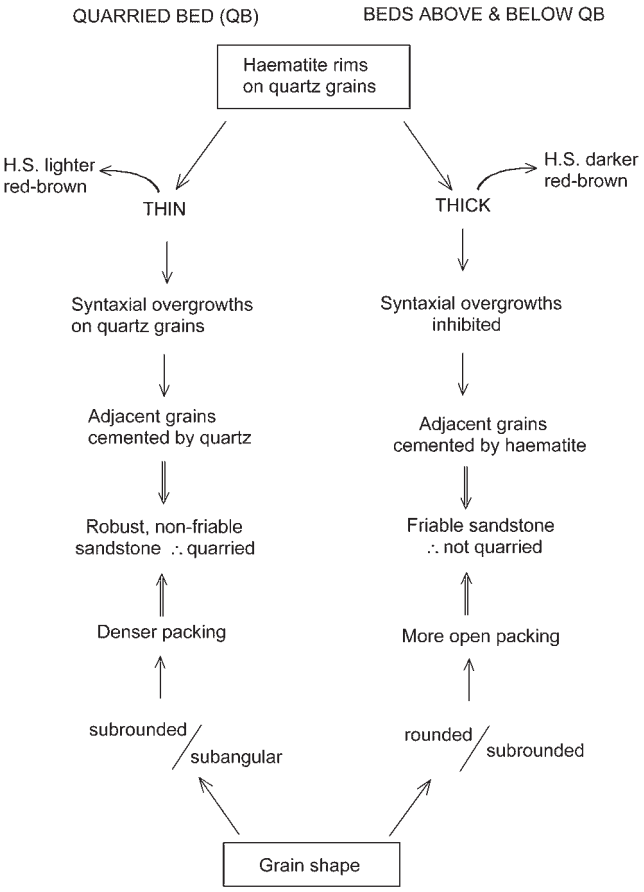

Figure 8. Petrographic distinctiveness of QB.

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From Genealogy to Geology

Gladys Dinnacombe

Figure 1. General geology map of the area and the extent of the workings in 1899.

Researching my family history has been an interesting hobby and as I got further back in time to the 1850's, I discovered my ancestors had been brickmakers in Newcastle-under-Lyme, North Staffordshire (Figure 1). In the 1851 Census, my great-great-grandfather lived with his family, next door to his brother and his family. All the members of the family who were old enough to work, and that included the female members, worked in the brickworks as brickmakers. Looking at old maps of the area led me to believe that they worked in Springfield Tileries, the local brick pit known (during my lifetime) as Wheatly's Brick and Tile Works. (Figure 2). My memories during the late 1950's and early 1960's are that the buildings of this company could still be seen although

Figure 2. Wheatly & Co. Ltd. in 1989.

I do not know if the pit was still being worked at that time. Further research led to the study of old maps and a small advertising booklet dating from 1930 (Platt 1995) was discovered. This booklet showed small drawings of the tiles produced and how they were made. This will be discussed later.

I was now 'hooked' on finding out more and having come to a temporary halt on the genealogy I decided to look at the geology. Because of the pottery and coal industries, there is quite a large amount of geological information about this area. Briefly, the rock formations in this area are mainly of Carboniferous age, although there are some areas of Permo-Triassic sediments. A borehole at Apedale, indicated ancient volcanic debris, overlain by mudstones and sandstones of the Millstone Grit and Coal Measures. Above the Coal Measures are the red beds of the Etruria Formation (Figure 3). These were laid down on an alluvial plain and consist of mudstones of many colours and sandstones. Besly and Turner (1983) suggested that the red beds were formed due to fluctuations of the groundwater table, which were induced climatically and from the iron-rich sediments themselves, during and shortly after deposition. It is the mudstones of the Coal Measures and the Etruria Formation which have been and still are, the source of clay for the manufacture of bricks and tiles, using the local coal for firing the kilns.

In 1850, Dobson (seeCeloria 1971) wrote a treatise on brick making. He gave some interesting information about the uses of bricks besides buildings: ‘a common turnpike road bridge over a railway

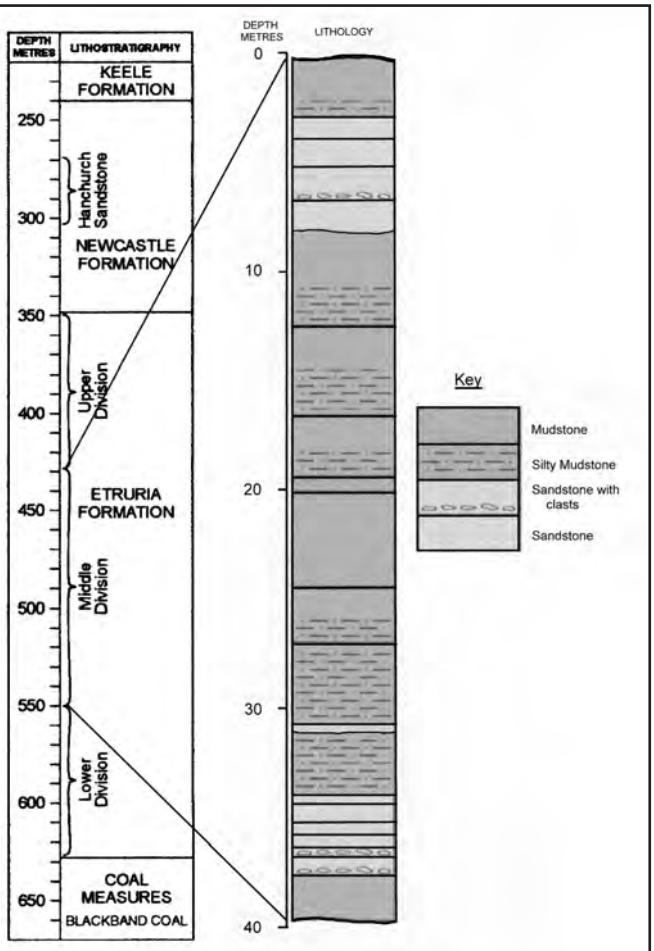


Figure 3. Stratigraphic column showing Coal Measures and Etruria Formation, and the detailed column of the Middle Division of the Etruria Formation, based on sedimentological logs (after Rees and Wilson 1998).

requires for its construction, in round numbers, 300,000 bricks; and the lining of a railway tunnel of ordinary dimensions consumes about 8000 for every yard in length, or in round numbers, about 14,000,000 per mile'. At this time, the brick industry was well established in this area, and the beds of the Coal Measures have now been worked for brick clay, for around two centuries.

Bricks from this area were well-known because they were strong blue bricks (although red bricks were also made), made from the Etruria Formation. Today there is one main brickmaking facility, using clay from four quarries in the Etruria Formation and firing them in advanced tunnel kilns, although the Coal Measures are still used for brick clay in the northern part of this area.

BGS divide the Etruria Formation into three parts, Lower, Middle and Upper (Figure 3). The Lower part consists of mudstones with several local sandstones. The mudstones include greenish-grey laminated mudstones and reddish brown or variegated mudstone with no laminations. There are also some thin coal seams or carbonaceous beds. The Middle part is the thickest part (105 - 167m) and consists of variegated mudstones (no laminations) with reddish brown mudstones and lenses of sandstones. The variegated mudstones can be yellowish-brown, greenish-grey and purple. The Upper part consists of variegated and reddish brown mudstones. In the top 20 to 30 metres, small calcareous nodules are found. These cause problems in the firing process as they can cause the fired bricks to flake and break.

So what did my ancestors do as brickmakers? Dobson (1850) (see Celoria 1971), in his treatise on the manufacture of bricks and tiles, gives us plenty of information. First of all, the clay had to be dug out. This was done in Autumn and the clay heaped up and left to weather over the winter. In North Staffordshire, however, the clay had to be ground first before being left to weather because of small pieces of limestone which occurred in the clay. The weathering process prevents lamination and the clay was considered to be properly weathered if it ran through the fork when turned over; otherwise it was left for further weathering. An illustration in the advertising booklet shows the men digging out the clay using pickaxes and shovels and loading the clay into wheelbarrows. By April, the clay was ready to be turned over with shovels and then was either put into a pugmill or through rollers. A pugmill was either a wooden tub shaped like an inverted cone with an upright revolving shaft to which knives were attached so that they cut and kneaded the clay, or a hollow cast-iron cylinder powered by steam which did the same kind of thing. As the clay was kneaded it was gradually pushed through the mill. Water was sometimes added to give plasticity. If rollers were used, they were generally powered by steam also.

The advertising booklet of Wheatly and Co., which was published in 1930 is entitled 'The Good Old Way' (Platt 1995). The company dates back to 1819 although the area had been worked for clay much before that date. The company started by making common bricks and agricultural drain pipes. When the proprietor realised the potential of the deposits in his clay pit towards 1870, the business expanded. In the 1881 Census, Samuel W. Wheatly stated that his occupation was Estate Agent and Brick and Tile Manufacturer. As Estate Agent, he managed the Butterton Estate (owned by Lady Pilkington) and many of the estate houses were built with bricks from his brickworks. The census also gave his place of birth as Wickham in Huntingdon, so he was not a local man. The booklet tells us that in clay pits at Springfields, there were as many as twenty different seams, free from lime, which enabled a wide range of mixtures to be obtained without resorting to the use of artificial colouring matter. By this time, there had been some changes in the clay making process. According to the booklet, the secret of the wide range of pleasing brick and tile colours is because of the close attention given to the mixing process as well as the large number of different seams available at this site. Up to 8 or 9 different clays may be used in obtaining the correct mixture for a particular product.

The mixing process itself intrigued me. Measuring was done by the barrow load; barrow loads of each of the required clays being tipped into trucks and then properly mixed. This mixture was then taken to the grinding sheds and ground ready for the next process. At the time of the printing of the booklet, the grinding was done via a series of rollers from an automatic feeder, the only one of its kind in Staffordshire at that time.

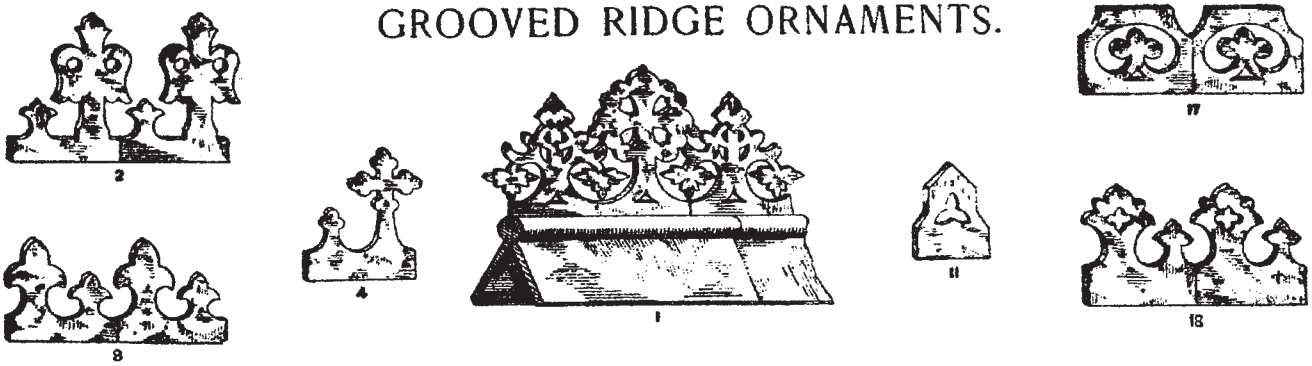
After grinding, the clay mixture was soaked with water to induce plasticity and allowed to lie in stacks called rucks. The clay lay there for several weeks or even longer. This process, called souring, could be affected by the weather unless roofs were made over the rucks. When ready, the clay was then taken to be pugged followed by another short rest before being ready for moulding. The booklet shows 14 different types of bricks and tiles.

WHEATLY & Co.,

SPRINGFIELD TILERIES, NEWCASTLE, STAFFS.
SANDBACH COLLIERY, COBRIDGE, BURSLEM, STAFFS.

ALL GOODS ARE MADE IN BLUE, RED, BROWN, AND BUFF COLOURS.

GROOVED RIDGE ORNAMENTS.



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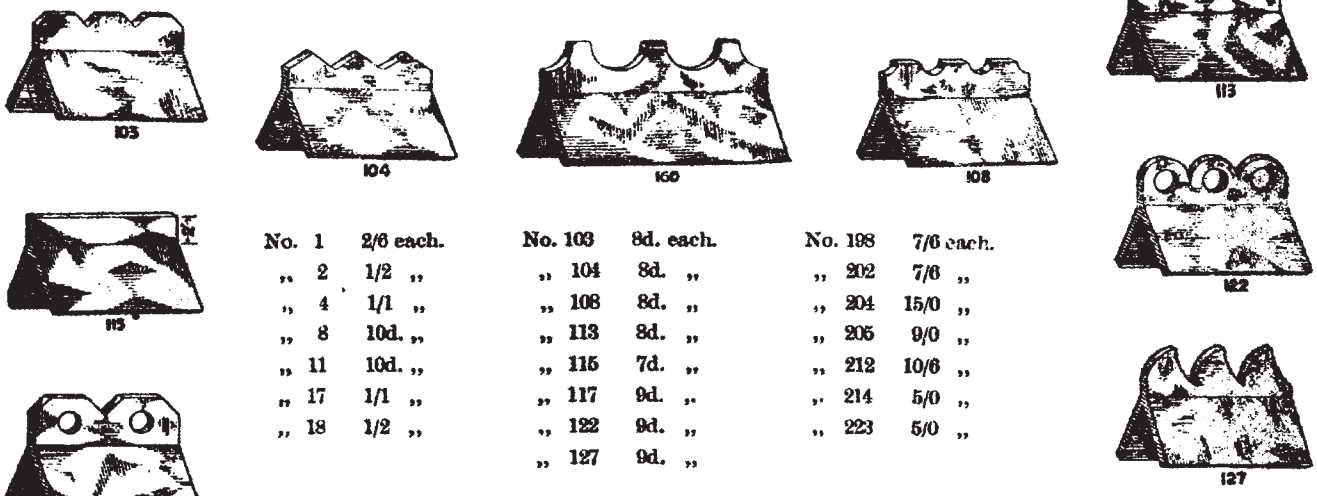

No. 1	2/6 each.	No. 103	8d. each.	No. 198	7/6 each.
,, 2	1/2 ,,	,, 104	8d. ,,	,, 202	7/6 ,,
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,, 8	10d. ,,	,, 113	8d. ,,	,, 205	9/0 ,,
,, 11	10d. ,,	,, 115	7d. ,,	,, 212	10/6 ,,
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RIDGE FINIAL.

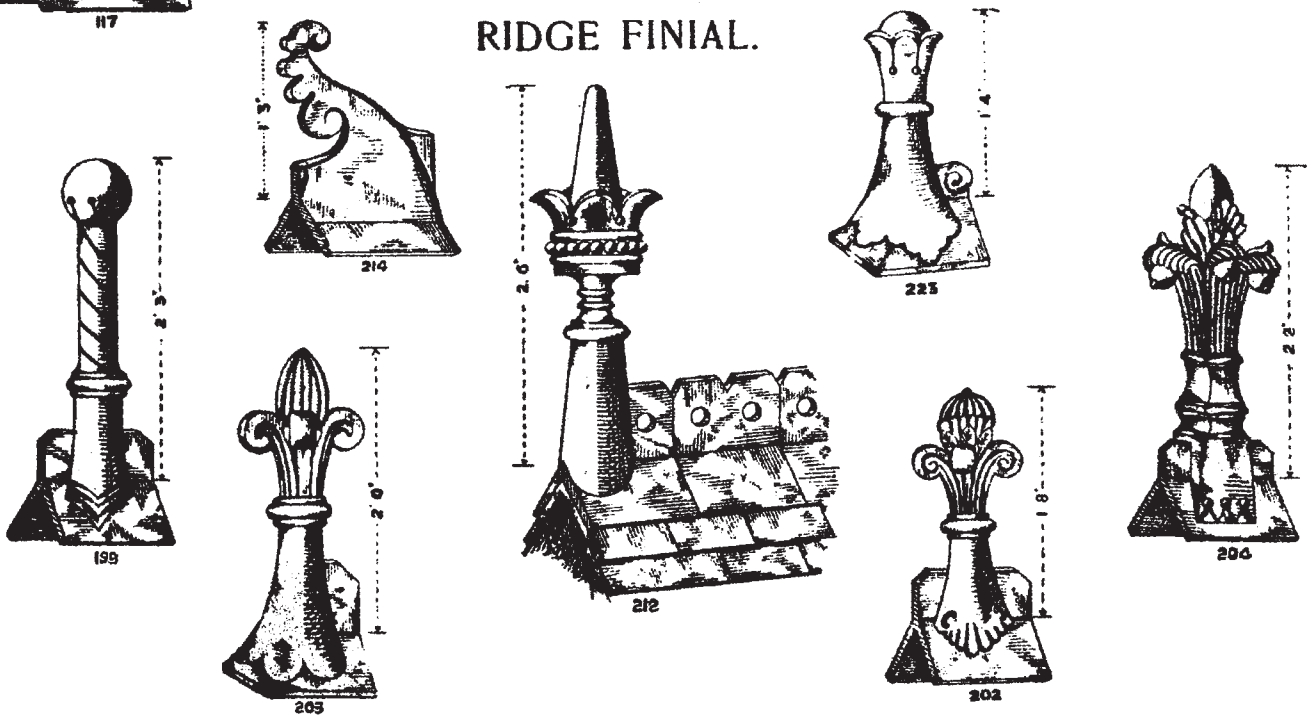

Figure 4. Illustrations from the 1893 Catalogue (Sears 1893).

The Contractors' Compendium and Complete Catalogue of 1893 (Sears 1893) has four pages of illustrations of different bricks and tiles produced by Wheatly and Co. at that time (Figure 4). As well as the normal flooring and roofing tiles, there were grooved ridge ornaments, fast top ridges and ridge finials. There were gable and wall tiles, ridge tiles and ventilating ridge tiles. Bricks included best blue bricks as well as blue vitrified stable paving and kerb bricks. There were also terra metallic garden edging tiles. Best blue bricks cost 62/6 per 1,000 while ordinary roofing tiles were 37/6 per 1,000. Ridge finials were priced at between 5/0 and 15/0 each.

To return to Dobson's Treatise, brickmaking in this area of Staffordshire is described in great detail with illustrations of various machines. This section of the Treatise was written by R. Prosser. In 1850, 100,000 bricks could be made weekly during the brick season. The usual brick yard had a 5 horse power steam engine, a set of horizontal rollers, a pug mill and six drying houses as well as nine ovens or kilns. When the clay was ready, it was moulded into brick and tile shapes. This was done by hand. The clay was cut into pieces slightly larger than the moulds. It was then kneaded and bumped before being thrown into the mould quite forcefully. It was beaten down in the mould to increase its density. If drainage holes were needed, then these were done at this point. The tiles and bricks were then laid out on the floor until they were sufficiently set ready for the next stage in the process. Dobson gives some interesting information about the weight before and after firing. (Table 1)

Table 1. Total loss of weight in drying and burning

196 ounces, the weight of the brick wet from the mould
46 ounces, the weight lost by drying, or $23^1/_2$%
150 ounces, the weight of a brick ready for the kiln
21 ounces, the weight lost in burning, or 14%
129 ounces, the weight of an ordinary blue brick

In this area the kilns were circular, domed over at the top and called cupolas. Fire holes were openings left in the wall, and these were protected from the wind by a wall built around the kiln (Figure 5). Up to 8000 bricks could be fired in one cupola. Dobson also details the total cost of manufacture and the selling price (Table 2). At this time, 1850, it seemed that being a brick-

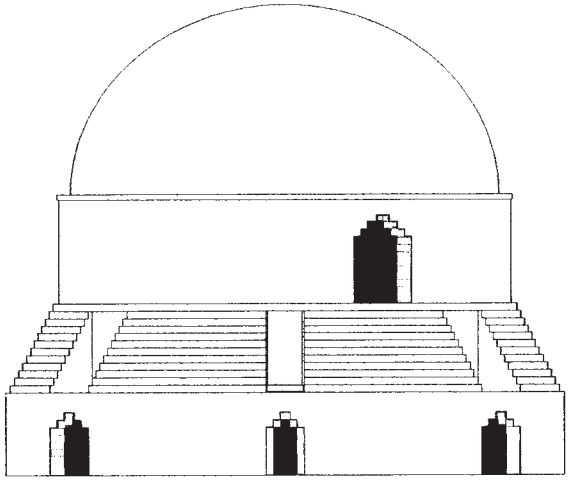

Figure 5. Diagram of cupola (after Dobson1850).

Table 2. The cost of manufacture and selling price.

		£ s d
Clay getting	per 1000	0 1 6
Tempering and moulding	" "	0 4 9
Setting oven, firing and drawing	" "	0 1 6
Coals, 4 tons at 8s. 4d., divided amongst 8000	" "	0 4 2
Duty, 5s. 10d., with 5 per cent added	" "	0 6 $1^1/_2$
Rent, machinery, clay, contingencies and profit	" "	0 9 $11^1/_2$
Present selling price for ordinary blue bricks		1 8 0

maker was only a part-time job, in that during the winter there would be no work. Dobson stated that, by being more systematic and by using buildings designed specifically for the purpose, brick making could become an all year round occupation. No wonder that families working in the brick industry during the early 1800's were poor!

Before being fired, as techniques improved, the bricks and tiles were fettled or dressed, so that any small bits adhering from the moulding process that were not required were removed. Horsing, another technique, obtained a camber on the tiles so that they were more efficient in use. By 1930, the time when their booklet was published, some tiles were being made by machine but Wheatly and Co. were proud of themselves as they still produced

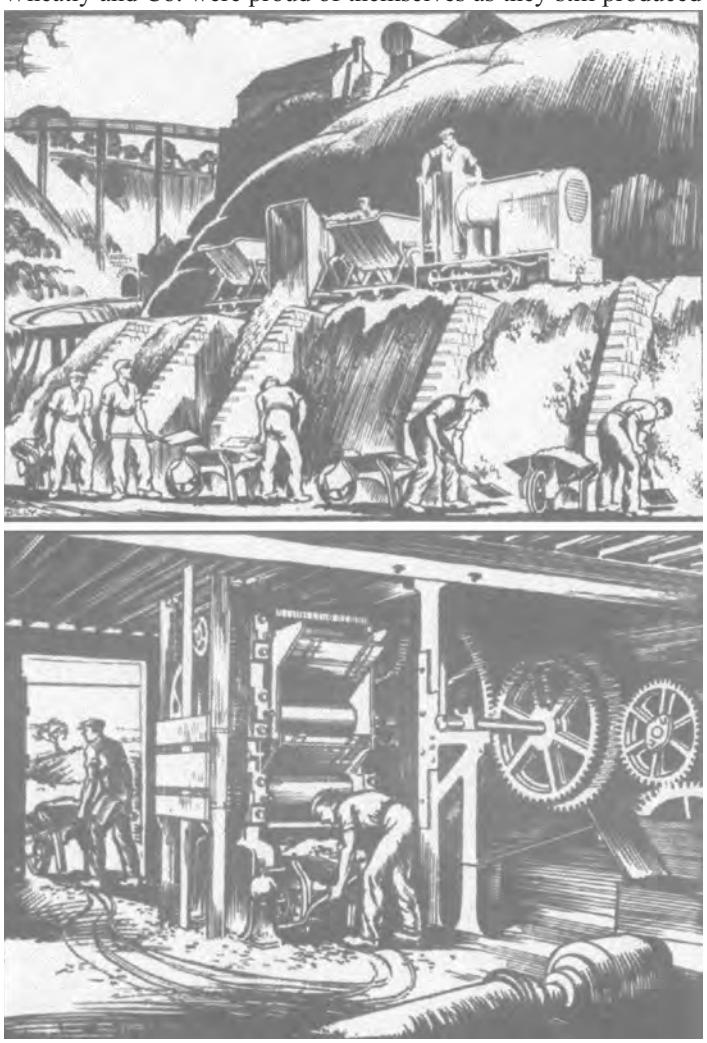

Figure 6. Two of the small woodcuts depicting men at work (Platt 1995).

quality hand made tiles. The final page of this booklet shows a series of small woodcut style pictures showing different people at work (Figure 6). There is also a copy of a photo of some of the staff employed at Springfield. Despite close scrutiny I have not yet found any of my ancestors.

Today, only one main manufacturer of bricks and tiles remains in this area and their main factory is across the road from where my mother lives. This brickworks has the longest kiln in the country and produces many kinds of bricks. Their website offers a great deal of literature about bricks and their use. So how has brick-making changed over the years? One important feature today is the consideration of the impact on the environment caused by the manufacture of bricks. This means that quarries are restored after being worked out and also chimney emissions are regulated. The bricks themselves are all moulded by machine, many different types being produced. These include perforated, frogged (bricks with depressions in one or more surfaces) and engineering bricks. There is also a range of special shaped bricks which includes angle and cant, arch, bonding, bullnose, capping and coping, cill, plinth, soldier and spiral. I wonder what my ancestors would have thought of brickmaking now!

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Book reviews

Geological History of Britain and Ireland edited by Nigel Woodcock and Rob Strachan, 2000, Blackwell Science, 423 pp, £29.50 (paperback) ISBN 0632036567.

This "Must Have" text provides an excellent framework for understanding the regional geology of the British Isles and, where relevant, how this fits within a global context. The book replaces, not just updates, the highly regarded Anderton, Bridges, Leeder and Sellwood's 1979 A Dynamic Stratigraphy of the British Isles.

The text is directed at wide range of readers from the undergraduate to the professional "needing a regional overview". However, as a health warning - first year students may find parts hard going.

The content is reasonably up-to-date, with the text freely highlighting current areas of controversy. The breadth of the information reflects the industrial and academic backgrounds of the twelve contributors, and the editors have done a good job in removing the inconsistencies usually apparent in multi-authorship textbooks.

There are 21 chapters organised into six key themes: Introduction; Northern Margin of Iapetus Ocean; Southern Margin of Iapetus Ocean; End of Iapetus Ocean; Variscan Cycle and Consolidation of Pangaea; Post-Variscan Intraplate Setting. Two introductory chapters provide a sound setting for the main body of the book. In particular, they address key principles such as stratigraphy, palaeogeography, structural regimes and global-scale processes. Each of the five main sections contains a comprehensive overview before looking in detail at the relevant parts of the British Isles.

The chapters carry their own References and Further Reading lists, the latter containing useful notes and subjective comments such as "a valuable source of ....". This is an appropriate approach for a text of this nature, and is far preferable to the alternative of endless pages of bibliography collated at the end of the book. However, be prepared to check both lists because the in-text references are sometimes listed under "Further Reading". As citations are only used in the Figures and Tables, the text is uncluttered for the general reader; however this approach may frustrate the researcher.

Much use is made of diagrams, charts and tables to illustrate key concepts. These figures clearly convey their information, sometimes in simple cartoons but often as well-designed composite charts which simplify complex data. Also, there is a comprehensive index, an essential ingredient of a use-friendly textbook.

Unfortunately there are annoying editorial errors. When the word "Cambrian" floats across a diagram the reader is left wondering from where it came. But when the text references the wrong diagram, particularly when it is in a group of four similar diagrams, the less confident reader might assume it is their lack of understanding which is at fault. However, as I did not find many of these, I doubt that it is any more serious than in other lengthy tome.

Although this is a long book, it lends itself well to a range of selective work, such as:

- understanding where the bits that constitute the British Isles came from, when they came, the impacts of their arrivals, and their subsequent effects

- mugging-up on, say, the Variscan, and why SW England is different, and what was happening to mainland Europe at that time

- or maybe you're just about to attend an OUGS conference in Dublin and want to know what is in this often neglected area of study!

Overall, the text provides an informative, impressively comprehensive coverage of our regional geology which is approachable, reader-friendly and, even allowing for the editorial slips, an essential component of the bookshelf (even if you only own a small handful of geology books).

Joan Taylor BA Hons

Beneath our Feet: the geology of Islington; an explanation of how an exhibition in an urban environment was conceived, constructed and received.

Diana Clements BA (Open), Islington Museum and The Natural History Museum

Abstract

In an urban environment where no geology can be seen and even topography is often not apparent, except to walkers and bikers, it was a challenge to set up an exhibition on the local geology that would have relevance to the inhabitants of Islington. The method chosen was to demonstrate how the local geology has influenced the development of the area. This involved tying in local post-glacial history with geological structures such as the Thames Valley and its terraces, the surface rocks and their uses. Material included many relevant maps, pictures and photographs, a 3-D model showing topography and deep geology, a model of a deep bore to the Basement, touchable rocks, reconstructions of ancient environments and displays about relevant local industries. The exhibition was remarkably successful, as visitors who knew nothing of geology were able to relate to it. The basic formula can be adapted to other areas and would be particularly useful in urban environments.

Background

The London Borough of Islington possesses a wealth of old maps, pictures and photographs housed in its two reference libraries. These collections have formed the basis of many exhibits on local history in the libraries and elsewhere in the borough. They also own a small number of artefacts and in 1989 a curatorial post was established. However, Islington had to wait until 1993 to acquire premises – a shop at 268 Upper Street. This was achieved through the hard work of an active group of Friends who also set up the Islington Museum Trust to help run the Museum. The space was to be used for temporary exhibitions, drawing on its collections where possible. A small notice in the local paper alerted me to the existence of the museum and I suggested that geology should be included with other historical material in future plans. I was invited to participate, along with 11 other Friends, in the first of the museum training sessions, which subsequently proved invaluable, as they were extremely practical. I chose to continue my researches into the geology of Islington as my project, and was invited to submit it as an exhibition proposal, which the trustees approved. Hence, in 1997, the exhibition became a reality.

Format

The 3-D geological model was the starting point for introducing geology to the people of Islington and remained a pivotal point. Research into the details of local water supplies and uses of the rocks in the area took me into a wealth of documents on local history. It soon became quite apparent that geology was a very important element of the area's development and so I resolved to research it from this angle. Out of this arose the idea of dividing the exhibition into sections, and I wrote up the project under the following headings:

1) The underlying geology
2) Influence of geology on communications
3) The importance of water
4) The influence of geology on forestry and farming
5) Rocks as a resource

This formed the basis of the proposal accepted by the Trustees and research could begin on locating the details, pictorial material and artefacts. The display was to be mounted for 3 months and storyboards and the model would form the core of the exhibition. These were to be durable enough to be reused around the borough as appropriate.

The Story of Islington

The story of Islington begins with the underlying surface rocks. The most extensive Ice Age glaciation, the Anglian, 400,000 years ago, reached as far as Finchley, just a few miles north, and forced the Thames into its present position (BGS 1994, Sumbler 1996). As the ice retreated, extensive sands and gravels were deposited along the banks of the river. In the south of the borough Thames Gravels show a sequence of terraces with progressively younger gravels down slope. These provide evidence of alternating cold, tundra-like landscapes populated with animals such as the woolly mammoth and woolly rhinoceros, and interglacial warm spells when a very different landscape prevailed, much more comparable with the African savannah. There were straight-tusked elephants, hippos, lions, deer, bison and horses all using the Thames and its tributaries as a source of water (Merriman 1990:14). The underlying London Clay is much older: about 50 million years. From the fossils found in these clays, both in Islington and from coastal exposures such as the Isle of Sheppey, we learn that the whole of southeast England was some 100m deep under a Mediterranean-type sea with sharks and turtles swimming above. The coastline away in the Midlands was experiencing a sub-tropical wet and warm climate comparable to present-day Malaysia (Sherlock 1935:Pl.II).

These surface rocks have determined the character of land use through the ages, and in particular since the last retreat of ice some 10,000 years ago. But it is probably the structure of the London Basin that has had the most profound influence. The 'crumple' of the London Basin is the result of the African plate colliding with the European plate some 1,000 miles away. Although, at this distance, we do not have impressive mountain chains such as the Alps, we do have minor folding which has had a direct bearing on both surface and sub-surface drainage patterns (Merriman 1990:6). The diversion of the Thames 400,000 years ago heralds the beginning of evidence of habitation in the London area with Swanscombe Man, dated at about 350,000 years, and earlier handaxes being found along the banks (Merriman 1990:11).

It was the Romans who first put London on the map. When they invaded in 54 BC they crossed the Thames at its lowest crossing point. Much of the area was swampy so they chose the harder ground for their city. Londinium was founded on the gravel-covered bluff that is now Ludgate Hill, upon which St. Paul's Cathedral stands. This had the added advantage of providing a defensible position, bordered by both the River Thames and the River Fleet, with the boggy ground of Moorfield to the north (Hall & Merrifield 1986). They could draw water from both these rivers as well as the small tributary of the Wallbrook, which ran through the City. Water could also be abstracted from the underlying gravels.

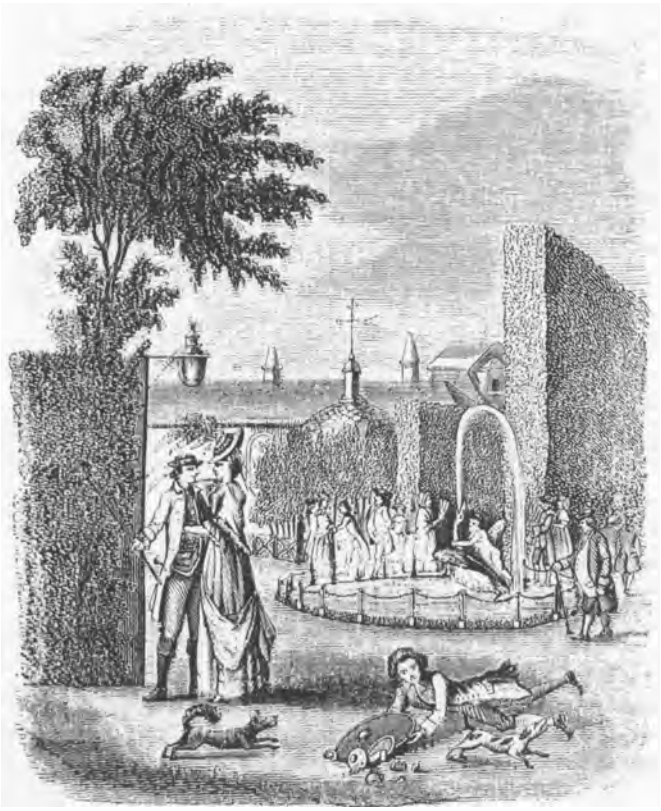

Figure 1. Bagnigge Wells Gardens from an old print (Pinks 1865).

The availability of water was a critical factor in all early habitations. Here the geology is of prime importance. The Fleet, which borders south Islington on the west side, is fed by a spring line on Hampstead Heath between the permeable Bagshot Sands, which cap the Heath, and the underlying impermeable London Clay (Cameron 1934). The Hackney Brook, which is long-since lost, flows through Holloway into the River Lea and is likely to have originated at the same junction (Vestry Room, 1735). The Fleet cut a deep valley along its route to the Thames. It is now entirely covered but its course can mostly be followed by reference to the topography, particularly along the length of Farringdon Road, to its confluence with the Thames under Blackfriars Bridge. The valley, from Kings Cross downstream, cut through the overlying Thames Gravels into the London Clay exposing a second spring line in the south of the borough ('JE' 1638, Stow 1598:43, 46). This is where the early monasteries were established in the 12th Century, just outside the City walls. They were also able to utilise the Fleet for navigation and power. Later the springs were to provide watering holes and 'health spas' to the inhabitants of the metropolis. Sadler's Wells is the most famous one now, but there were many others such as Bagnigge Wells (Figure 1), St. Chad's Well, London Spa, New Tunbridge Wells and White's Conduit all claiming the efficacy of their chalybeate water. Londoners would come up the hill to Islington to breathe the fresh air, taste the waters and enjoy the entertainment provided by the 'Tea Gardens' (Pinks 1865, Manley 1990, Foord 1910, Nelson 1811:105, Harris 1974:38, 43, Sugden 1984:13, 27, 33).

The gravels themselves provided another source of water with shallow wells sunk into them. In fact, until the early 19th century the extent of the metropolis was dictated by the Thames Gravels. This was roughly from the Thames up to the Marylebone Road, and in Islington, up to Highbury Fields. Hampstead and Highgate drew water from the springs and gravelly-sands of the 50 million year old Bagshot sands with the only other pockets of early habitation on the intervening London Clay along the banks of the Lost Rivers (Tindall 1977). Once cleared of its forests for the building of Londinium, this intervening area became very important for agriculture. For the most part the slope towards the river allowed the clay to be well drained and apparently very fertile. Initially crops were important (Fitzstephen 1191 *in* Stow 1598:23) but with the close proximity of Islington to the City, the land came to be used almost exclusively as pasture for dairying and provision of hay for the horses (Nelson 1811:106-111, 206-215, Wyatt 1989). The fields also provided rest and fattening for livestock driven from the north to the market of Smithfield (Foreshaw & Bergstrom 1980).

It is the deeper geology that has influenced later development. By the early 1800s technology was sufficiently developed for deep bores to be sunk beneath the London Clay to abstract water first from the permeable Thanet Sands and soon after from the Chalk (Buchan 1938, Whitaker 1889:Vol. II). With the proximity of Smithfield Market, Islington had always boasted large numbers of public houses where ale was brewed on the premises (Richardson 1988:35-41). Brewing and distilling were now able to expand and become an important industry in the south of the borough.

The thick sequence of London Clay is an easy tunnelling medium and North London is well served by the underground system. South of the Thames, where London Clay is thin or non-existent, they have to rely on overground trains. The Thames Water Ring Main is a more recent addition, supplying London's water since 1996.

Until the 20th century the surface rocks were an important resource in the building of Islington. The glacially derived Brickearth, lying on top of the gravels in the south of the borough, has been used since Roman times for brickmaking. As intensive dairying began to cause disease amongst the cattle towards the middle of the 19th century, the land owners seized the opportunity for a better living and turned their meadows into brickfields

Figure 2. Brickfield with moulder's bench in foreground and clamp behind. Tile kilns are in the distance. Taken from '*The brickmaker*' (Illustrations of Trades 1860:70 in London Metropolitan Archives).

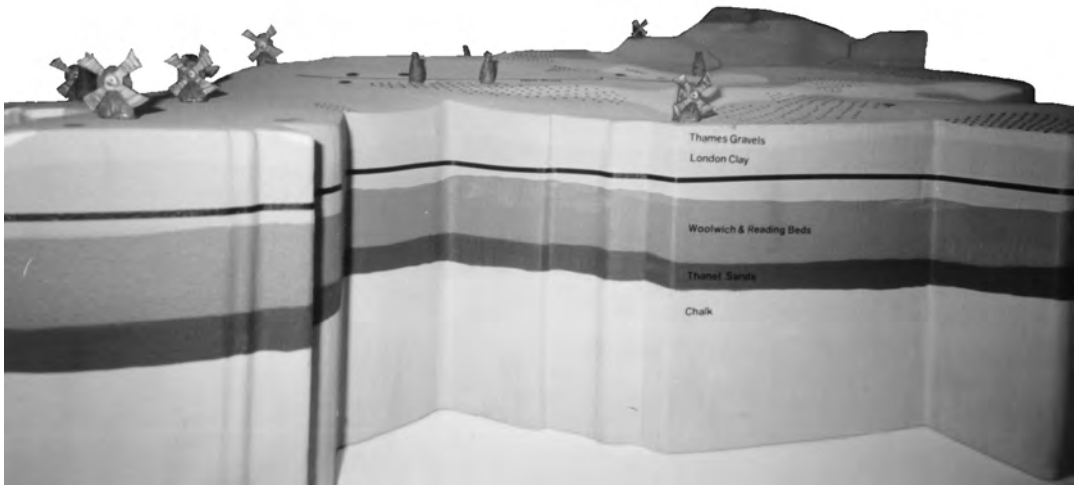

Figure 3. The model showing Thames Gravels overlying the London Clay, Woolwich & Reading Beds, Thanet Sands and Chalk.

(Nelson 1811:111). Brick making was a very localised industry. The clay was mixed on the field and the bricks stacked into 'clamps' for low-temperature firing (Figure 2). Building often began soon after, on the very spot from which the clay was removed (Cosh 1990, 1993). The sandy horizon at the top of the London Clay (the Claygate Beds) was used near the Archway, and in the Highgate and Hampstead areas. Extensive tunnelling during the 19th century for the railways and the Archway Road provided a temporary source of London Clay but this had to be mixed with sand and Chalk to provide a suitable material. Tile and pottery manufacture required hotter temperatures and kilns were mainly sited close to the Fleet, adding to the pollution that already existed in that area from the industries related to the market at Smithfield (Dobson 1850).

The gravels were another important resource. As early as 1284 there are accounts of the Baghot Sands being dug from the top of Highgate Hill to improve the route through the 'Hollow Way' (Archway Local History 1986). They were later used in the laying of the railways. The younger Thames Gravels were used much more extensively for both roads and buildings. Mr. Sadler, a surveyor of highways, came across his famous Wells while excavating gravel (Harris 1974:36).

Now Islington is the most densely populated borough in London and these resources are buried beneath the houses. Once water distribution was established, habitation spread over the London Clay areas, precipitated by the increase of the population in Victorian times and the arrival of the railways. Holloway, with its wide road for marshalling the animals on the way to Market, started out as an 'out-of-town' shopping area with some of the first department stores (Richardson 1988:95). Street names occasionally give us a glimpse into the topography and geology beneath (Willats 1988), but otherwise the present residents of Islington must rely on holes in the ground to take a look at the geology that had such a profound influence on the development of their area.

Method

The storyboards formed the backbone of the exhibition. In all there were 12 A1 boards divided between the 5 sections and colour-coded appropriately. They were professionally designed and manufactured, and each section is able to stand alone if required for small displays elsewhere. The storyboards could only contain the outline story accompanied by selected pictures so the wealth of additional material turned up during research was used throughout the exhibition within the displays as appropriate. Artefacts were borrowed from local museums where possible.

The model

A contour map of Islington was obtained from the planning office and the local geology superimposed (BGS 1994). Borehole data was gathered primarily from *Water Supply of the County of London* (Buchan 1938) and Whitaker (1889:Vol. II), and collated to show the deep geology on the side of the model (Figure 3). The model was constructed from the data supplied, and painted to show the geology in the same colours as the BGS map. The scale chosen was approximately 1:7000 with a vertical exaggeration x 9. The main communication routes were shown as a perspex overlay. The Islington street map was doctored to leave only the main routes and then photographed onto the perspex. Former waterways were painted over the surface geology (Cameron 1934, 1935, Bromehead 1936, Barton 1992). The routes of the man-made New River and the Regent's Canal were also added. The locations of ancient springs and wells were marked by numbers. It was extremely satisfying to note how well both rivers and springs tied in with the geology. Locations of former brickfields and gravel workings were shown by cross-hatching (see section on resources). Former locations of tile kilns and windmills was also shown. The model was mounted on a plinth and covered with a clear perspex lid.

The underlying geology

The focal point of this section was an 8 foot 'borehole' that was a scale model of the 300m bore to the Basement sunk in Tottenham Court Road in the 1850s (Whitaker 1889:Vol II 165-8). Technically this proved to be one of the most challenging aspects of the exhibition as we used 'real' rocks. I collected some of the samples myself; others were supplied by Thames Water, Geotechnical Division, who discards some of their cores periodically. GEOU also helped

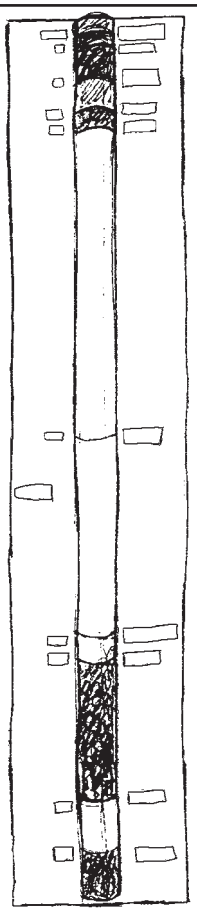

Figure 4 Sketch of the model borehole constructed for the Islington Exhibition of *Beneath our feet*.

me out. The display 'bore' was made up by an acrylic supplier from a clear perspex pipe, cut in two lengthways and joined in the middle. It was fitted with half moon dividers to represent the appropriate depths, and supplied with a backing sheet and glue for us to fix once filled. We assembled the 'borehole' on site and the episode sticks in my mind as the only real panic point in the mounting of the exhibition, but the end result made it all worth while (Figure 4). The 4" cores from Thames Water were larger than the 4" diameter of the tube and so had to be pared down. I had previously broken down the solid lithologies into small fragments and these, along with the sands and gravels, were packed dry into appropriate sections. Inevitably there was some settling when the bore was mounted vertically. With more time, the addition of PVA might have prevented the movement but it takes a long time to set. The bore was attached to MDF board, with space either side for captions, using transparent nylon thread across the surface and secured either side with capped screws. A metal ledge was screwed under the bore for increased security. The finished article is really quite heavy and required several people to help in fixing it to the wall.

Figure 5. Invitation.

The rocks in the borehole were also represented by handling samples (Figure 5), which we arranged in a long line stratigraphically. Initially we used perspex cubes but on subsequent occasions white paper plates have worked just as well as long as they are replaced when worn. The accompanying labels included information on how the rocks were used in the area.

In the original exhibition I borrowed fossils found in Islington from the Natural History Museum. London Clay fossils have become pyritised and are thus very unstable. They need to be kept at a constant low humidity level. We displayed them beside reconstruction pictures in a locked glass cabinet, which also contained silica gel to absorb any excess humidity.

A copy of the 1925 North London geological map (Cameron 1925), and the most recent edition (BGS 1994) were displayed under a perspex sheet to complete this section.

The influence of geology on communications

The 1805/6 map of Islington (Burdekin 1805/6) provided the focal point for the location of communications throughout the borough. Postcards were purchased and postcard-sized pictures copied to illustrate the key aspects. These were tied into the geology by captions and linked to the map by numbers. This proved very popular with visitors.

Additional information was displayed by a mix of artefacts and pictures with appropriate captions which extended the story and the links with the geology. Information on early man in the borough came from English Heritage who supplied me with a list of appropriate archaeological sites. Subsequently these have been published by MOLAS as *The Archaeology of Greater London* (2000) with maps of locations through the ages backed up by details of the finds. *Prehistoric London* (Merriman 1990) gives a flavour of the pre-Roman environment and Irene Schwab's booklet on *The Archaeology of Islington* (undated) was another useful source of information. It provided a link between the communication routes and the Roman artefacts belonging to the Islington Museum. The Guildhall Library was able to supply a wealth of information on Smithfield Market and its successor, the Caledonian Market, both of which relied heavily on routes through the borough. The London Canal Museum lent us artefacts pertaining to the Regent's Canal, which cuts across the south of the borough. Malcolm Tucker, an industrial archaeologist, also provided valuable information on how the canals were constructed, using the excavated London Clay for lining purposes (pers. comm.). Pictures were acquired from the London Transport Museum to illustrate the importance of both the overland and underground railways in the history of Islington. The routes of both are largely dictated by the geology.

The importance of water

This section involved the most extensive researches. The natural rivers, the ponds, and most of the springs had mostly been covered over by the middle of the 19th century. An early source of information was provided in 1598 by Stow, who gives a description of the lower reaches of the Fleet and the springs that tumble into it from the Clerkenwell area. One of the most exciting discoveries was a similar description, located in Camden Archive library, accompanying a drawing of the Fleet from its source on Hampstead Heath to its confluence with the Thames, signed 'JE' and dated 1638. The document is thought to be a copy of the original, and is a subject for future research. The positions of the springs were from many sources, mainly detailed maps of Islington (Vestry Room 1735, Rocque 1745, Burdekin 1805/6, Tyrer 1805). Useful descriptions were found in Barton's *Lost Rivers of London* (1992), Foord's *Springs, Streams and Spas of London* (1910), the Victoria County Histories (1985), *Islington Entertained* (Manley 1990), and in the numerous histories of the borough, in particular Pinks (1865), Nelson (1811) and Lewis (1842). Pinks provided drawings of some of the spas not located in the libraries. Further reference to *Water Supply of the County of London* (Buchan 1938) reveals how many of the earlier boreholes were sunk for the brewing and distillery industries.

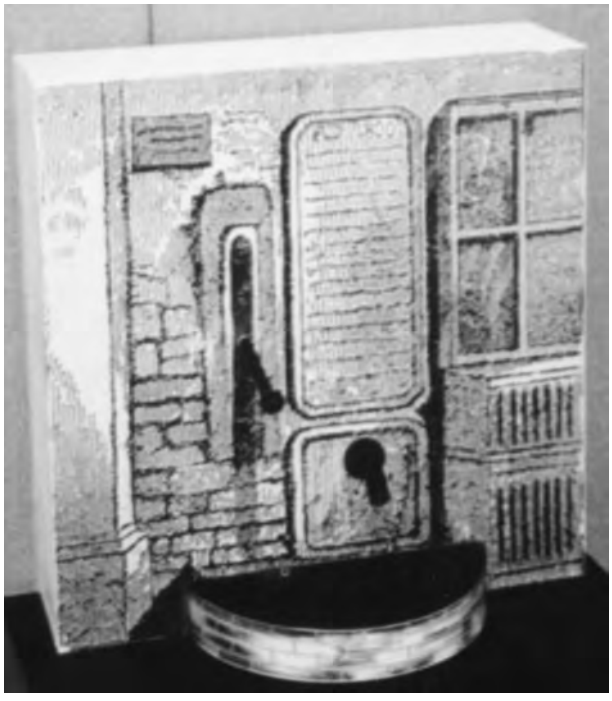
Figure 6. Model of the Clerks' Well constructed for the Islington Museum. Illustration from Pinks (1865).

This information was displayed as a map and postcard display, much the same as for the communications exhibit. This time the map used was the 1805 map of Clerkenwell (Tyrer), as it is in this area, situated on the Thames Gravels, that most of the locations are found.

The display of artefacts centred on the springs with their associated Tea Gardens and entertainment, and the subsequent brewing industry. Whitbread kindly loaned materials, which supplemented those owned by the Islington Museum.

An important addition to this section was a model that was made for us of the Clerks' Well. This had a picture of the well (Pinks 1865:274) blown up and pasted to a rectangular box and covered with perspex for protection. A metal tray and pipe were added with a cheap fish-tank motor to pump water around. The sound of running water was an effective way of highlighting its importance (Figure 6).

Influence of geology on forestry and farming

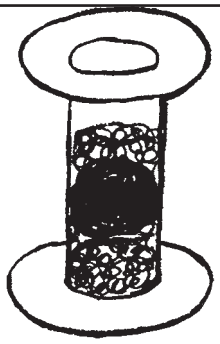

Figure 7. Sketch of the model constructed to demonstrate different permeabilities of rocks.

A simple model to demonstrate the permeability of gravels and the impermeability of clay was constructed to show how drainage plays an important part in agriculture. It has dry gravel at the base, then a layer of clay followed by a second layer of gravels, this time with water on top (Figure 7). The model could have equally been used to demonstrate spring lines.

The transition from tundra through mature mixed forest to crop cultivation, dairying, market gardening, brick-making and finally urbanisation was mainly illustrated with pictorial material accompanied by captions. The libraries produced numerous pictures relating to the dairying industry to which artefacts were added. These, and other examples related to farming, were borrowed from the Islington Education Artefact Library Service.

Islington used to be an important recreational area and the Islington Museum owns a number of paintings and prints illustrating the open fields with the City beyond. We were delighted to be able to display these as well as an important oil painting borrowed from the Central Library. As this was a valuable item, the loan was dependent on an efficient security system.

Rocks as a Resource

Brickmaking provided the focus for this display. The process is well documented in Dobson (1850) and I used his line drawings, supplemented by the raw materials and finished examples, to show how the bricks were manufactured on the fields from which the clay was dug. Pictorial material of brickfields and tile kilns illustrated locations labelled on the geological map that I had drawn for the storyboard.

Research for the map was one of the more time-consuming aspects. I wanted to demonstrate the former extent of the brickfields and gravel workings (Figure 8). The 1994 version of the North London geological map (BGS) marks many of these; other

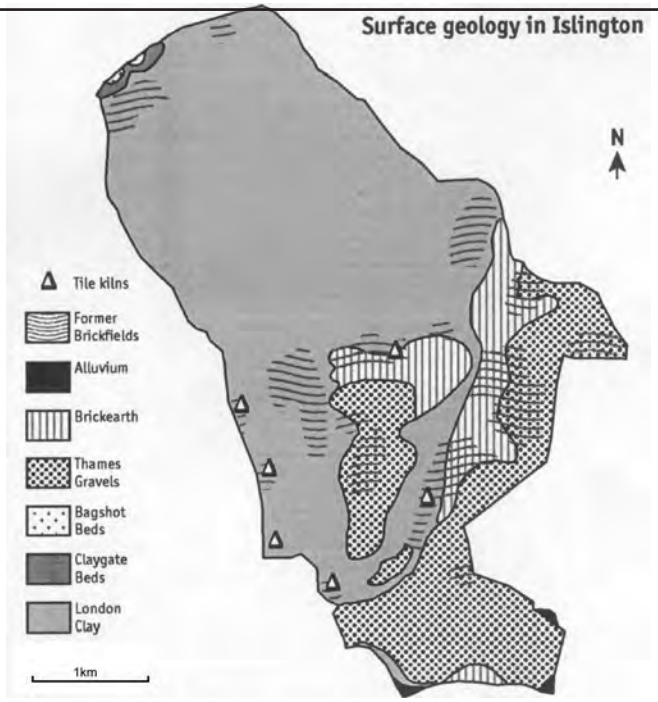

Figure 8. Surface geology in Islington with sites of former brickfields and tile kilns added.

data was obtained from older local maps (Tyrer 1805, Burdekin 1805/6, St. James's District 1839). One of the most useful was Dent's 1805 tithe map that is backed up by details of the owner at that time and use of the fields. Information also came from the Victoria Histories (1985:15, 20, 22, 72), Nelson (1811:111), Lewis (1842:50) and Harris (1974:39).

Following the exhibition, this section has been successfully displayed on its own elsewhere.

Mounting of pictures and captions

Apart from the storyboards which were printed professionally, all the additional pictures and captions were created in-house. Existing postcards and maps (purchased from Islington Library Archives) were used where possible but other pictorial material was colour-photocopied, including some of the black-and-white images. Photocopies were made on 100gsm paper where possible. Permission was sought for all the material used. Text for captions was produced on a PC and printed on 100gsm paper. Attention was paid to uniformity of typeface, text size and margins. 14pt is the minimum recommended size for text. Everything was mounted on foamboard, using spraymount for photographs. This was a very time-consuming exercise, but I was ably assisted by the Friends and the result was worth the effort.

Educational activities

While the exhibition was running we hosted a number of educational workshops. These were mainly aimed at top primary level. We split a class into two groups and while one group worked on activities relating to the exhibition, the other went elsewhere for a fossil workshop. We also ran building stone walks for both school groups and adults. A teachers' pack was produced which described the fossil workshop and the building stones walks, as well as instructions for making a contoured geology model as described below and an activity on researching relevant street names.

Duplicating the Concept

The concept can easily be reconstructed in any area with emphasis on aspects that are locally important. For geologists it involves a certain amount of research into the history to establish what links, if any, can be made. The 3-D geological model is an expensive item but provides a key display, as visitors can see where they live and how the underlying structure, rocks and drainage relate to their experience. Street names can often provide a link to the geology and topography. A less expensive model can be made using foam-board cut around each contour and overlaid with the geological map. These are then glued together for a 3-D effect. If the model is still too complicated, a similar objective can be achieved by mounting the geological map on polystyrene for local visitors to stick flags in showing where they live.

In an urban environment the actual rocks are not usually visible and visitors unfamiliar with geology are often surprised to find what lies beneath their feet. The invitation to PLEASE TOUCH on any display of rock samples goes down well (Figure 5). Information on how the rocks have been used as a resource can provide another link. Fossils, on the other hand, are usually fragile and some sort of untouchable display is desirable. They look well in a bookcase, covered by perspex and fixed at eye-level, as this demonstrates the stratigraphy at the same time. If it is possible to obtain reconstruction pictures, these are a very effective way of communicating how life and the environment have changed over millions of years. Our 'borehole' showing the deep geology was somewhat problematical to construct, and is too long and heavy to carry around easily. Instead, rock samples could be arranged stratigraphically beside the fossils or, if the deep geology is not shown on a model, a section using foamboard or card can be drawn out. An added educational activity could be to measure out actual borehole depths on a piece of string and 'lower' children down the borehole to see what rocks they encounter, and to describe each environment as it is reached. Simple models demonstrating geological processes will always enhance an exhibition, particularly if they can be interactive.

Research on the geology of any region starts with geological maps. 1:10,000 (6") scale are particularly useful, if available, and older versions often contain information not reproduced on their modern equivalents. The BGS has facilities for research. In London these are available free of charge at their premises within the Natural History Museum but the material available for study is not nearly as extensive as at their headquarters near Nottingham, where borehole data is available for large areas of the country. The current and older Regional Guides (eg Sumbler 1996, Sherlock 1935) and Memoirs (eg Bromehead 1925, Whitaker 1889) are another valuable source of information. Topographical maps are usually available from the local planning office.

History is best researched through the local archive library. There will probably be useful pictures available, although high-quality photographs can be expensive. Permission must be sought to use them in displays and publications. There is usually no charge when used for educational purposes. Many libraries reproduce old maps and pictures for sale. Local Archaeological and Historical groups can be very helpful and they will also have a list of relevant publications. General histories like the Victoria County Histories (1985) and The London Encyclopaedia (Weinreb & Hibbert 1993) are worth looking at, and most archivists will be able to hunt you out the most relevant local maps and books if you explain carefully what you are looking for. In the London area the Guildhall Library and the London Metropolitan Archives both carry a large selection of the pre-Ordnance maps, some of which are for sale. Further source of descriptions and photographs for the outer London Boroughs are write-ups of field meetings in the Proceedings of the Geologists' Association.

If you are planning to display relevant artefacts, bear in mind that museums often require long lead-times for loans. Some of the larger museums make a charge, and all of them will expect you to insure their items. Think about what security levels you can offer before you get too far with negotiations. Some items require stable humidity, and prints and textiles will often demand low lux levels. All loans and pictorial material should be acknowledged. Most institutions dictate the wording.

The colour coding of sections helped our exhibition to look bright and lively. We also paid considerable attention to the layout and mounting of the display. The professionally produced storyboards were our biggest expense but temporary displays can easily be mounted on foamboard or even quality coloured card or paper with good effect. Mounting individual pictures and captions on foamboard can be very time-consuming and it is essential to have a suitable cutting board, a steel rule and a stock of sharp blades. However, it is a relatively easy and cheap means of creating a professional-looking display. Those with the PC skills to draw their own maps and diagrams have an additional tool.

Costs

The costs involved will depend very much on the degree of sophistication required. In Islington the storyboards were professionally designed for long wear. By contrast, a simpler display of 6 storyboards in Uxbridge Library including maps, text and illustrations was mounted on coloured paper for just a few pounds. The total cost of mounting the Islington Exhibition was nearly £7000, but to produce a comparable display using cheap materials could cost less than £100.

Acknowledgements

I would like to thank everyone at the Islington Museum who encouraged me to mount this exhibition, and raised the funds to make it possible. Also to the Friends and volunteers who helped both with the presentation and guiding visitors through it while it has been on display. I thank the Geologists' Association for inviting me to bring the exhibition to Brighton for the Earth Alert conference where it was presented as *Beneath our feet: you can do it too*. The Curry Fund of the Geologists' Association sponsored the Brighton display and the booklet that accompanies the exhibition. My thanks also to Diana Smith for suggesting to Jane Clarke that she approach me with the idea of producing an article for this Journal, and to my daughter Sarah, for drawing the sketches. I hope that local OUGS groups may find some of the ideas useful.

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Author

Diana Clements is currently working in the Palaeontology Department at The Natural History Museum. She also runs classes and field trips for the Adult Education Department, is a Friend of the Islington Museum and, in 1998, assisted on the display for the Earthlab exhibition. Her main interest remains with the geology of London.

Book reviews

Santorini Volcano Geological Society Memoir No.19 (including geological map at scale of 1:20,000) by T H Druitt, L Edwards, R M Mellors, D M Pyle, R S J Sparks, M Lanphere, M Davies & B Barriero, 1999, Geological Society, 165pp £70 (hardback) [£35 to Fellows of Geological Society] ISBN 1862390487.

Santorini is a field of volcanoes, and this Memoir of the Geological Society gives as comprehensive an account of volcanological research as is available anywhere, which sadly means that reading it can be very hard work. Yet, it is rewarding work because even when it proves painful, the layout and structure of the text, together with the plentiful black and white maps, diagrams and plots, the reader can learn a great deal about the activity of these volcanoes which have left their mark on the region since ancient times.

Following archaeological work at Akrotiri in southern Santorini by Mariatos during 1939, it is now accepted that it was the cataclysmic eruption of Thera, one of the several edifices within the Santorini volcanic field, in the Late Bronze Age which ended the Minoan Civilisation. The precise date of that eruption is still not known, but the research has shown that a sea water filled caldera existed prior to that event which means this volcano is particularly hazardous because a submarine eruption could happen at any time. In the chapter describing the history of Santorini, the research, described in such absorbing detail, reveals that the volcano has erupted violently on numerous occasions before and since the Late Bronze Age. It is this tendency for explosive eruptions of short duration with severe human consequences, as well as the creation of calderas that led to Santorini being declared one of the five laboratory volcanoes in the Environmental Programme of the European Commission.

There have been three International Congresses devoted to Santorini: in 1969, 19 78 and 1989 and much of the research generated from these meetings is published in this volume. As well as the chapter on the history of the volcano, there are chapters about the geological and tectonic setting and the development of Santorini volcanic field in space and time. These three chapters are very interesting and not difficult.

The next three chapters are the most scientific and concern the study of the Thera pyroclastic deposits: the compositional zoning of minerals and petrology; analyses of cumulate nodules; and the geochemistry, isotopic composition and petrogenic modelling. In addition, one of the chapters is devoted to short-lived radionuclides in the Santorini volcanics. In these chapters, there is commendable thoroughness in the description of the application of the various techniques and how each contributes to the construction of the history of Santorini and, hopefully, makes prediction of eruptions more reliable. If the reader can spare the time and effort, here is an opportunity to learn all about modern volcanology, although geophysics is not included. The final chapter provides a lucid synthesis.

The two appendices include analytical methods and errors; and tabulated analytical data of samples collected by a number of workers. Major and trace element analysis is given for each sample which is then grouped according to stratigraphic layers so it is easy to locate them on the excellent large, loose geological map. There is a good index and list of references.

If you plan a trip to Santorini, and you study this book beforehand because it is not of a size to fit snugly into either a pocket or a rucksack, there is no need to be bewildered when you get there. Equally, for anyone wishing to learn how petrogenic models of explosive volcanoes are constructed, or who needs to reason the role of magma chamber processes versus crustal assimilation, this volume would be invaluable.

There is plenty of interest in the book besides the detailed scientific work but at the price of £70, it is hard to justify a purchase.

Jane Randle, BA Hons (Open), M.Phil (Open)

The Diatoms: Applications for the Environmental and Earth Sciences edited by E.F. Stoermer and John P. Smol, 1999, Cambridge University Press, 469 pp. hardback £70 ISBN 0521582814.

Diatoms are microscopic algae found almost everywhere where there is water. However this is not a book about their life histories. Their chemical signature varies according to climate, acidification or eutrophication of their environment and it is this characteristic that makes them such a valuable research tool. After a short introduction by the editors, in which they explain the applications of diatom research in the environmental and earth sciences, there follow 23 research papers by leaders in their specific fields of research.

First are seven papers related to diatoms as indicators of environmental change in flowing waters and lakes; then come four papers on diatoms as indicators in extreme environments; five on diatoms as indicators in marine and estuarine environments; then six papers on a variety of other applications including archeology, forensic science and atmospheric transport, and finally a chapter on diatomite. This last is probably the most accessible to those whose whole scientific background is in the earlier courses in geology. A final chapter by the editors looks to the future in this field of research suggesting among other things that the time has come for more detailed studies in the formalities of taxonomy and nomenclature.

Each chapter of the book stands alone and each has its own excellent and extensive list of references. The chapter introductions are like thesis abstracts and give a good indication of the area covered and make it easy to see if the chapter is relevant to one's own purposes. Many students could benefit from reading the introduction and summary sections of each chapter to get a general overview of the field.

Strangely this is a book that you could, if you were so inclined, read from cover to cover. It is not a work I would recommend to undergraduates who have not yet studied any honours level courses, nor to those with a very narrow single science background. The style of writing varies from chapter to chapter and some are therefore much easier to read than others. The illustrations are well produced throughout although some graphs are better studied with the aid of a magnifier. The reference sections are especially useful for those who wish to delve deeper into a particular aspect or see at a glance how much work has already been done in that area. For these alone the book is a useful reference for someone starting out on more advanced research.

This is the kind of book I would like to have readily available in the university library, preferably in a reference only or restricted loan section, so that it was there when most needed. However at £70 it is not a work I would purchase for myself, nor can I imagine anyone else doing so if working on a tight research budget or grant.

Margaret Enger BA(Hons) (Open) MSc (UEA)

Making thick “thin” sections - an update

Jane Clarke

In 1985 I published an article on how I made thin sections of rock in a home workshop (Clarke 1985). Since then, my research has been focussed on studying the histology (microstructure) and microarchitecture of vertebrate fossils. Cutting thin sections of fossilized bone requires a slightly different technique - hence the “update”.

Fossilized bone is softer than “hard rock” but harder than unconsolidated sediments; it therefore requires very careful handling. Rock sections are usually cut to 35µm but the details required by the histologist are often visible through a polarising microscope at a thickness of ~70µm, sometimes they are visible in thicker sections but, if the section is cut too thin, the features disappear. In some cases the feature can best be observed when focussing through a thick section. It varies from specimen to specimen and from feature to feature.

Another important factor is that if the sample comes from a museum specimen the chances are that it is very small. Even so, permission is often only granted for one section cut in a specific place to cause least damage to the fragment. Sometimes permission is given to serial section the specimen, i.e. cut as many thin sections as possible. This requires that each section leaves very little waste, i.e. very little ground away in the section-making process, so as to obtain as many sections as possible.

The technique I have developed for cutting sections of fossil bone is an adaption of my process for making thin sections of rock but cutting out the heavy grinding and wastage of sample.

I start by photographing the untouched specimen from all angles. This is a safeguard in case the specimen shatters in the cutting process and I can use the photos to help me to reassemble the specimen and encase it in araldite. Some delicate and fragile specimens need encasing in araldite before cutting but I try not to have to do so as the araldite is often harder than the bone and creates problems by undercutting at the grinding stage (i.e. the bone grinds away faster than the araldite).

If the plane of the section can be seen on the raw fragment then it is ground by hand using 400 mesh carborundum grit on (preferably) plate glass until it is completely smooth. If the desired section runs through the fragment then it has to be cut using a six inch diamond-coated saw (mine is home-assembled but lapidary saws are available) and then smoothed as before.

A microscope slide is prepared by, firstly, writing the specimen number/name on one end of the slide using a diamond engraving tool. This ensures that the identity of the specimen is always available. The other side is then roughened by hand using 400 carborundum grit on glass. Degrease both the flat surface of the specimen and roughened glass with acetone.

The flat side of the specimen is then bonded to the roughened side of the glass slide using Super Epoxy™ glue “strong enough to lift a car!” This is a two-tube epoxy which sets in 5 minutes. It also happens to have optical properties which do not interfere with microscopy. It is retailed by Plastic Padding, now part of Loctite UK Limited. Care must be taken to mix the two substances well but avoid creating bubbles if possible. The specimen must be pushed hard against the glass to eliminate any bubbles which are visible as silver areas when viewed through the glass. Leave to harden.

You now have a knobbly piece of bone stuck to a glass slide. The next task is to remove as much of that bone as possible without shattering it, thus leaving it usable for further sections. I use a ‘cutting jig’, sketched in Figure 1 and made for me by a friend

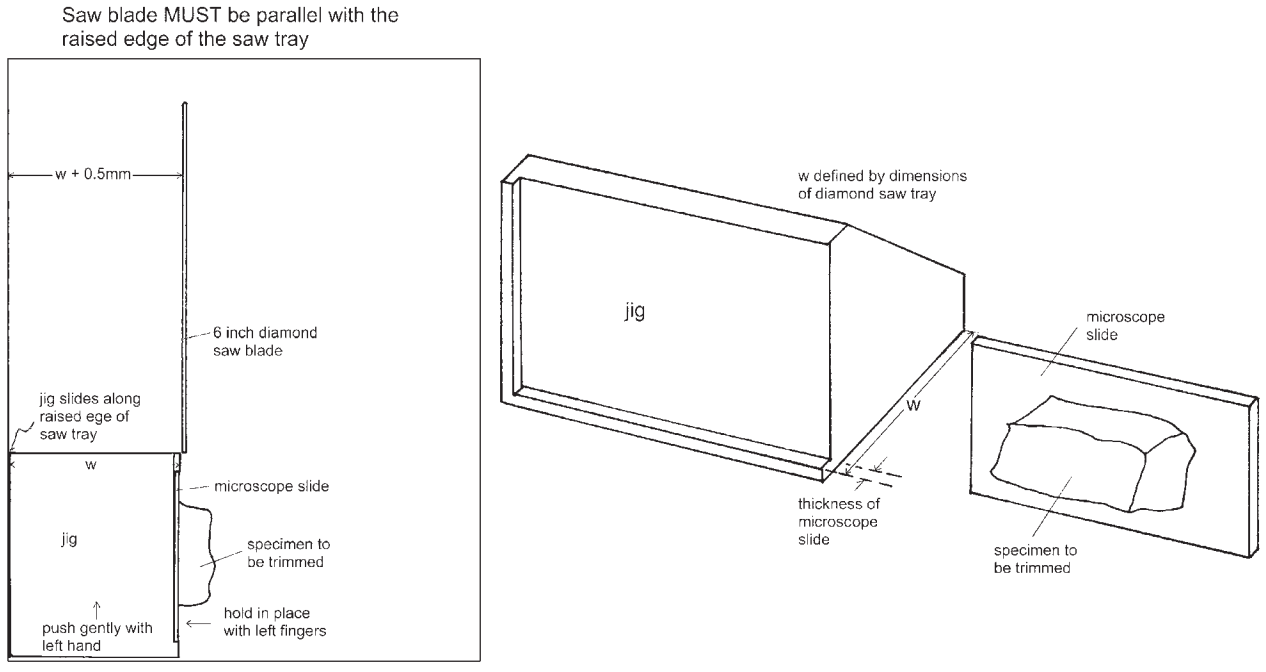
Saw blade MUST be parallel with the raised edge of the saw tray
w + 0.5mm
6 inch diamond saw blade
jig slides along raised ege of saw tray
w
microscope slide
jig
specimen to be trimmed
push gently with left hand
hold in place with left fingers
w defined by dimensions of diamond saw tray
jig
microscope slide
w
thickness of microscope slide
specimen to be trimmed

Figure 1. Configuration for jig and saw for trimming specimens when cutting thin sections.

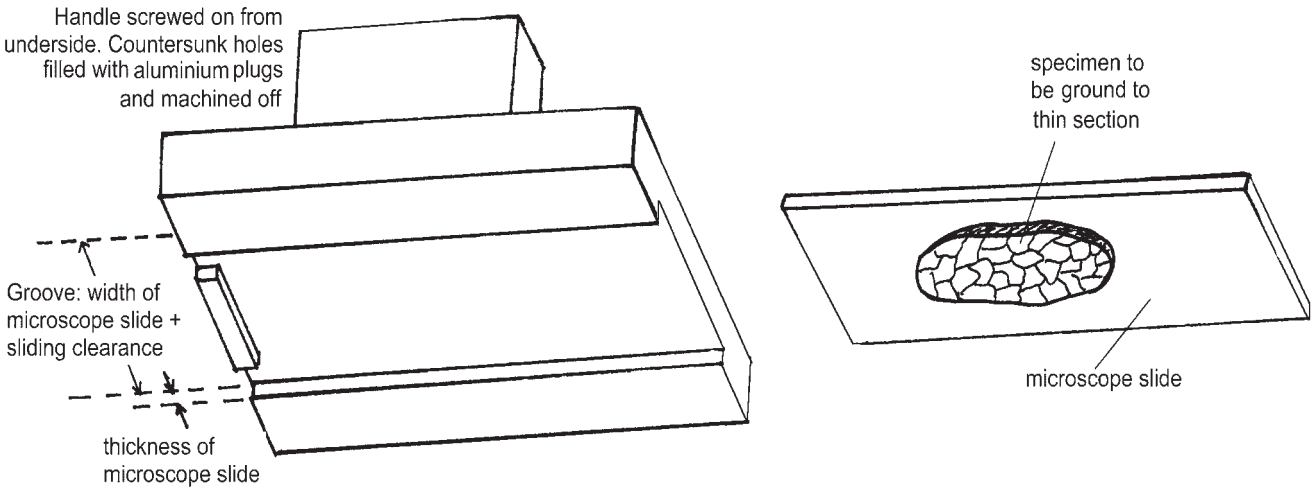
Handle screwed on from underside. Countersunk holes filled with aluminium plugs and machined off
specimen to be ground to thin section
Groove: width of microscope slide + sliding clearance
thickness of microscope slide
microscope slide

Figure 2. Jig for grinding thin sections by hand.

with a milling machine. The jig is made from an aluminium block with a recessed side to take the slide. Exact measurements are not given as the dimensions depend on the other equipment used. The jig is slid along the edge of the saw tray and fed past the saw blade using the left hand to keep the slide tight against the jig. The right hand steadies the cut-off portion of the specimen. This should result in a 0.5mm section attached to the glass slide and a flat-faced, slightly smaller specimen ready for smoothing for the next section. As the saw only removes about 0.5mm when cutting, only a 1mm length of bone has been removed from the specimen.

The glass slide with the 0.5mm slab attached is now ready for hand grinding. However, as bone is often filled with randomly dispersed authigenic minerals with a variety of hardnesses, keeping the specimen flat while hand grinding is not easy and can result in a wedge-shaped section. To prevent this I use another jig, illustrated in Figure 2; again exact dimensions are not given as they depend on the thickness of the glass used. Milled from a block of aluminium this jig allows fairly brisk grinding with 400 mesh grit on plate glass without the possibility of too much of the specimen being lost.

The section is ground down using circular movements, until it bottoms out at about 0.25mm. Further grinding is done by feel (without a jig) using 400 and 600 mesh carborundum grit on separate pieces of glass. Frequent inspection using a microscope enables the section to be ground to the desired thickness, grinding being stopped when the desired characteristics are observed.

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Book review

Fire in the Sea The Santorini Volcano: Natural History and the Legend of Atlantis by Walter L Freidich translated (from German) by Alexander R McBirney, 2000, Cambridge University Press, 258pp, £19.95 (hardback), ISBN 0521652901.

Recent television programmes have brought Santorini, classically known as Thera, to our attention as a cause of the fall of the Cretan Minoan civilisation and have introduced us to a number of more or less likely sites for the lost Atlantis, including Santorini. Students of S339 have met Santorini as a case study in the evolution of calc-alkaline magmas and will remember the videos of Richard Thorpe and Steve Blake demonstrating and obviously enjoying the island.

Fire in the Sea is a beautifully produced coffee table style book aimed at the general reader. Technical terms and methods eg plate tectonics, dating methods, etc are dealt with in explanatory boxes. It communicates both the scientific and historical interest of Santorini without the breathless hyperbole that seems to characterise TV geology and its treatment of serious science is accessible to the lay reader.

The book is in four parts: *Geological Framework* which describes the current geography of Santorini, its position in a subduction zone, its geological development, both sedimentary and volcanic and its faunal and floral palaeontology. The illustrations are excellent but a modern map, possibly as a pull-out would have been helpful here and throughout.

The Minoan Eruption describes the Plinian, phreatomagmatic and basin deepening phases of the event with clear technical explanations. The explosivity index is estimated as comparable with Krakatau. A chapter is devoted to dating – radiocarbon –1675 BC, tree rings and ice cores – around 1640 BC and Chinese records extrapolated by generations – 1600 ± 30 BC.

The volcano releases its secret discusses first the archaeology of Bronze Age Santorini and the excavations at Akrotiri the Minoan town buried in the eruption and described as a Bronze Age Pompeii but with no bodies and many (most?) possessions removed. The photographs of the Minoan artefacts and decorations are superb. The great geological breakthrough from the mid 1980s was the proof that there was a caldera including an island before the eruption and this accords with Plato's description of Atlantis, which is reproduced in full as an Appendix. The effects on Minoan Crete are also discussed in lesser detail.

The island is changing its appearance discusses the continuing evolution, particularly the last 500 years. The island is still active and the last eruption was in 1950.

This wide ranging book is fully referenced allowing the reader readily to follow up in more detail aspects of particular interest. The breadth of sources range from around 600 BC to 1996. It is a beautifully produced and very easy to read. It probably won't add much to your degree but it will give pleasure and is a must for those planning to visit this lovely place.

Was it Atlantis? The case is strong and more convincing than any other site I have heard of but in Friedich's words '… these arguments still do not give us a final link …'

Bill Willows continuing OU student

Geo Walk - Perranporth to St Agnes

Mike Hermolle

The Devonian sedimentary rocks of Cornwall are divided into two regions by a line running approximately from Perranporth to Mevagissey. Some authors refer to this as the Start-Perranporth Line (SPL) and extend it to Start Point in Devon (Figure 1). It possibly represents an ancient line of weakness, along which there was movement during the Devonian. To the north, sediments were deposited in the variable depth of water of the Trevone Basin, some of which was very shallow. These rocks include the oldest rocks in Cornwall: the Dartmouth Group, which are of Lower Devonian age. They are usually red, purple and pale greeney-grey slates. To the south deposition was in the deep water of the Gramscatho basin. The Gramscatho Beds are mainly interbedded greywackes and slates. The Cornish coast from Hayle to Perranporth is composed of the Porthtowan Formation: grey and greyish-green slates with thin beds of sandstone and siltstone deposited by turbidity flows.

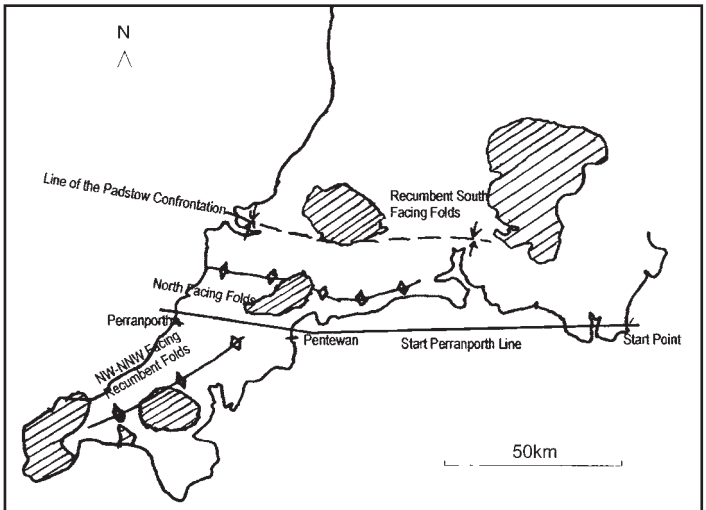

Figure 1. Outline of the geological structure in the south west of England. Granite batholiths are outlined.

The sequences on both sides of the SPL were deformed by Carboniferous tectonic movements, which produced northfacing folds trending E-W in the Trevone Basin and NW-NNW facing folds trending roughly SW-NE in the Gramscatho Basin. The differential folding either side of the SPL is possibly due to some dextral movement along the SPL during the initial stages of the Variscan Orogeny. Following the compressive stage of the Variscan Orogeny, post-orogenic collapse of the Variscides caused extensional WSW-ENE normal faults to develop.

During the Variscan, emplacement of the granites took place. Following emplacement the granite masses underwent alteration and mineralisation to produce the concentration of mineral wealth of Cornwall. Subsequent erosion, deposition etc led to the coast we see today. The effects of erosion on the coast have been increased by mining activity.

The main car park in Perranporth overlooks the beach. Parking is free from October to May but during the holiday period you can park all day for £2.00 with all proceeds going to local charities. There is also a pay and display car park in Wheal Leisure behind (inland from) the main street, St Pirans Road.

Hundreds of years before Perranporth became a holiday resort, the village made its living from mining. There are said to be hundreds of miles of galleries below the town, cliffs and dunes. Evidence of this activity can easily be seen in the cliffs below the Droskyn Castle Hotel on the Southwestern end of the beach (SW753544) (Figure 2).

Figure 2. Adits and Arches – Erosion by Man and Sea

The Castle Hotel is the best place to start if the tide is out (take extreme care and check the tide times before you go) as you will be able to see the cliffs, which are riddled with tunnels and the stacks, which are more due to mining activity rather than natural erosion. At extremely low spring tides you can walk right round the headland and visit Cathedral Caverns previously known as Vugah-en-Plunder (Figure 3). From the beach you can either make your way up the steps cut in the cliff below Droskyn Castle Hotel (although there is a bit of a scramble over the rocks to start with as the steps only go down to a platform which gives views of the cliffs), use the steps going up to the Droskyn Sundial or walk back around the headland and up Cliff Road. If you look down onto the beach when the tide has gone out, you will easily be able to see the ripple pattern with the hollows picked out by

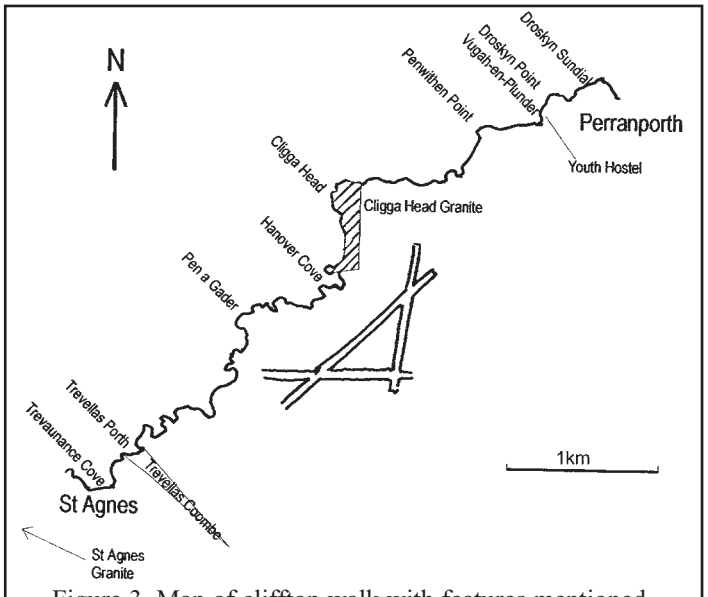

Figure 3. Map of clifftop walk with features mentioned.

black and brown tin ore. The effect of the dark areas is to give the beach a pattern similar in shading to mackerel skin. These deposits, and others which formed at the base of the cliffs, were once worked and provided a living for tin miners. If you look at the rocks that make up the stacks, you may be able to detect an inland dip to the strata i.e. roughly southeast. On the flat area above the cliff, take time out to look at the Droskyn Sundial, a Millennium project. The cardinal points are indicated by large granite pillars and the hours by small ones. This sundial is set to Cornish time and is therefore some 20 minutes behind your watch!

A word of warning as you set off along the coast – the cliffs are dangerous and there is no mobile phone signal over most of the coast path. If someone in your party has an accident you will have to make your way inland onto the higher ground to raise the alarm. Exploration of the caverns and adits is not recommended unless you are suitably equipped and can find an experienced guide.

Continue on now following the Coast Path signs. To the west of the Youth Hostel at Droskyn Point and below the Coast Path (SW752541) there is a large man-made cavern, off which are a number of passages. Along the coast you will come across a great deal of evidence of mineworking: spoil heaps, fenced-off shafts and so on. Some of the shafts have conical cages over them; these are designed to protect the public from falling in while allowing bats to fly in and out. The shafts in this vicinity are part of the Perran Great St George Mine which was itself an amalgamation of smaller mines. Dines(1994) reports that since 1815 the Perran St George group produced some 89,000 tons (other authors say 106,000 tons) of copper or and less than 200 tons of black tin. . There are no earlier records of output, although many of the mines are much older.

The path climbs slightly up a few steps at the side of which is a rock outcrop which dips roughly SW, i.e. inland. The outcrop is cut by quartz dykes up to several cm in width. The nearby headland also appears to have an inland dip. Because the strata dip inland the cliffs are less liable to be eroded and fall into the sea and, therefore, lead to the cliff form that you can see. As you round Penwithen point you will be able to see Bawden Rocks (or Man and His Man), which lie about 1km off St Agnes Head. Also in view are the tips of the famous greisenised granite outcrop at Cligga Head and the ruins of the Nobel Dynamite Factory. If you look back to the steep cove you have just crossed you should be able to see that the strata appear to dip almost vertically, but what you are looking at is the cleavage. The sea has been able to exploit these planes of weakness in the rock and has produced the cove.

As you climb the hill towards Cligga you pass an excellent example of a mine adit. Adits were used primarily to drain water from the mines. The water had to be raised by pumping it up to the level of the adit. You can take a look into this adit and you may get some idea of what mining conditions were like. You will need a torch and remember - it is very dangerous.

You now come to the main working area of Cligga Head. The vicinity is surrounded by spoil heaps and old buildings. Mining has taken place here for many years and produced mainly tin in the 19th Century. During World War 2 it was re-opened and produced a small amount of wolfram which was needed for armaments. Further prospecting took place during the ‘60s and ‘70s

Figure 4. Cligga Head greisen bordered sheet veins.

but was found to be uneconomic. Some of the granite has been extracted for roadstone. The dynamite works were originally founded in 1889 and taken over by Nobel in 1893. Although it ceased manufacturing explosives in 1905 it re-opened during World War 1 and employed almost 1000 people before closing at the end of the War.

A slight rise in the path leads to a fairly sudden revelation of the well known outcrop at Cligga Head (SW737537) which is world famous for its greisen bordered sheeted vein system. There has been some debate on the development of these systems. Initially they were believed to be thermal contraction joints but later authors suggest fracturing by high fluid pressure. Cligga Head has the characteristic striped appearance which is due to the close spacing of sub-parallel quartz veins. The vein fillings are mainly quartz with cassiterite and wolframite. There has been extensive kaolinisation in the area and both the granite and country rock are heavily kaolinised. The greisening, mineralisation and kaolinisation have made the Cligga Head area a classic site for the study of these processes.

It is possible to get down to the beach; iron spikes driven into the cliffside mark the path. However, it is very dangerous and should not be attempted alone. At beach level one can be able appreciate the extent of the workings and the difficult conditions under which the miners worked. Truro College runs a 1-day course, *Mines Field Trip: Cligga Head* which covers Cligga Head and the Wheal St George and Droskyn mines.

Like the St Agnes granite 4km to the southwest, Cligga is a projection of the Cornubian batholith. It is a roughly elliptical in shape approximately 600m by 350m and has been eroded to sea level on the western side. The granite continues to the south for

Figure 5. The Cligga Stock from the South

about 500m with the veins becoming less numerous and parallel and the degree of iron and copper staining increasing. If you make your way onto the headland north of Hanover Cove (SW737533) you should be able to see the fold structure in the granite veins (Figure 5). Another view, which compares with Moore and Jackson's classic section, can be found slightly further south, from the headland to the southwest called Pen a Gader (incorrectly Pen a Grader by the OS). Between Cligga Head and Pen a Gader the sea has exploited the weakness in the rock caused by kaolinisation and erosion is extensive and continuing, particularly in the vicinity of Hanover Cove.

Figure 6. Erosion at Hanover Cove.

The coast path now skirts the wartime airfield of Perranporth (or Trevellas). This airfield was constructed in 1940-41 to provide a base for fighter aircraft to defend the Cornish coast and shipping. A wide variety of nationalities flew from the airfield, which is still in use today by the Cornwall Flying and Gliding Club. From this area southwards the evidence of the flourishing copper and tin mining industry increases with capped shafts and spoil heaps in abundance. It is possible to find examples of minerals in the heaps. The coastline continues to be extensively eroded with small islands and stacks just offshore. Soon the path descends steeply into Trevellas Porth at the end of Trevellas Coombe. This is also known as Jericho Valley after the works at the head of the valley where tin ore from West Kitty Mine was processed. West Wheal Kitty mined the tin beneath St Agnes and had to transport the ore to Trevellas Coombe for processing as the dressing floors could not be set up close to the mine. The cost of transport was one of the contributory factors which led to the mine's closure. The valley is like many on the North Cornish Coast, the steepness of its sides indicating the resistance to erosion of its rocks. A short distance up the valley you will see relics of the Blue Hills Mine which was worked from as far back as the 17th Century. There is a small visitor centre where tin streaming is demonstrated during the holiday season. Just a few years ago the sands of Trevellas Porth provided enough tin ore for the production of ingots for commemoration purposes.

Figure 7. Trevaunance Cove

The steep climb up the other side of the valley is soon rewarded by spectacular views of Trevaunance Cove, the small port for St Agnes, which is about 800m inland. The extent of mining in St Agnes is immediately apparent with many engine houses and chimneys visible on the valley slopes. Much of the produce of the St Agnes and Perranporth mines passed through this port. The harbour was destroyed by storms in the early part of the 20th Century and it was never economic to replace it. The steep path descends the side of the valley to bring you to the end of the walk close to the Driftwood Spars Hotel which is open year-round for meals and drinks. There are souvenir and craft shops close by with more in the main village.

You can either take public transport back to Perran or retrace your steps; although you will be covering the same ground, seeing it from the opposite side gives a totally different impression and there are still some surprises.

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Author

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A journey through Namibia

Elizabeth & David Maddocks

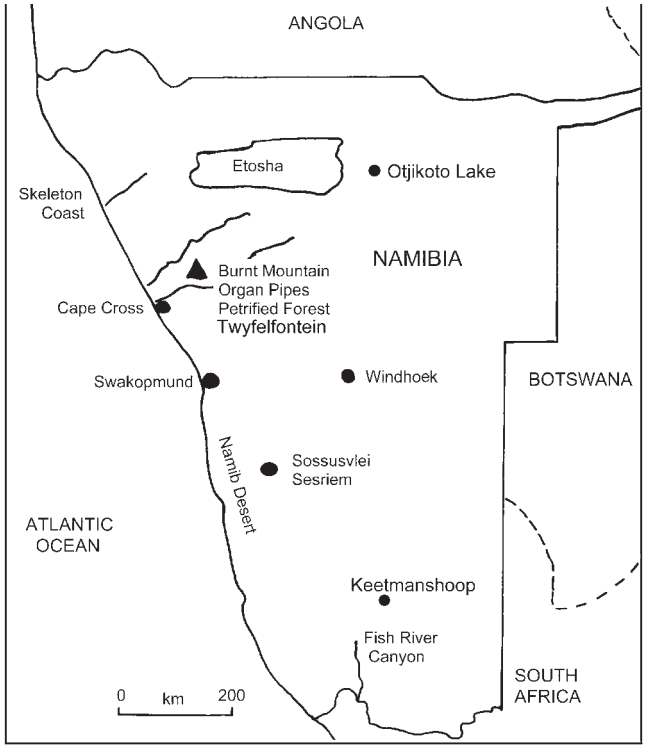

Figure 1. Sketch map of Namibia with relevant places marked.

In May 2000 we travelled 4,600 km to savour the wonders which this country has to offer in its geology and its wildlife. As it is largely desert or semi-desert there is little in the way of soil cover or vegetation, so it is a country of landscapes with geology displayed like an open book. We managed to track down a very good geology handbook, *Namibia – Fascination of Geology (*Grünert 2000), so we did not have to rely solely on our own interpretation of what we saw.

Introduction to overall geology of the country

The geological history of Namibia goes back about 2,100 Ma, when, in the vicinity of present day southern Africa, the Congo Craton lay to the north and the Kalahari Craton to the east of a primitive sea. These cratons were the cores on to which new land attached during mountain building. There were three phases of mountain building, the first between 2,100 and 1,500Ma, the second between 1,500 and 1,000Ma and the third began about 900Ma ago. The sea between the two cratons, the Damara Mobile Belt, started filling with sediments from the erosion of previously formed mountains. During this time there were tectonic movements and oceanic crust was pushed under the Congo Craton while the Kalahari Craton moved towards it. Eventually the two cratons collided; marine sediments and erosion materials were thrust upwards while magma rose and granite was emplaced.

Between 750 and 460Ma the huge folded belt of the Damara Mountains was formed and remnants of this can be seen today. At about the same time a shallow sea formed over the Kalahari Craton and sediments of the Nama Sequence were deposited; these rocks were not affected by the folding process and the almost horizontal layers cover much of southern Namibia. About 560Ma ago the continental areas of the southern hemisphere came together to form Gondwana. For millions of years the Damara Mountains underwent weathering and erosion and then about 300Ma ago a fourth phase of development began with the start of the Gondwana Ice Age. At this time Gondwana was close to the south pole and Namibia was affected by the glaciation for about 20Ma until what is now southern Africa had moved away from the south pole. The subsequent melting of the glaciers was the beginning of extreme climate change and the next 100Ma saw the spread of a huge hot, dry desert. Dune fields covered the land and later formed the Etjo sandstones which can be seen today.

The next significant phase in the development of Namibia was the breakup of the Gondwana Continent from about 120Ma ago and the extensive volcanic activity which accompanied it. The final splitting away of South America about 100Ma ago resulted in isostatic rebound and the uplifting of the Great Escarpment. From the start of the Tertiary there has been so much erosion that very ancient rocks are well exposed and, having been buried so deeply for so long, they are often metamorphosed.

Towards Etosha

We picked up our little Toyota Corolla at Windhoek Airport and made our way north to Etosha National Park (Figure 1). On the way we visited Otjikoto Lake which is situated in 700Ma dolomite and represents a karst lake which formed when the roof of part of a large cave system within the dolomite collapsed. As the floor of the cavity was lower than the groundwater level, a lake was formed. Otjikoto has very steep sides and is 100m across and at its shallowest is 55m deep but the full extent of the karst groundwater system is not known (Figure 2).

Figure 2. Otjikoto Lake.

"Etosha" means "great white place" and exactly describes the seemingly endless expanse of the Salt Pan. The National Park covers an area of 22,912km^2, most of which is approximately 1,200m above sea level. The Pan, which is 4,731km^2 in area, sits in the lowest part of the Owambo Basin and is approximately 110km by 60km. Looking across the Pan in the heat it was difficult to believe that during the Gondwana Ice Ages there was a huge glacier here which scoured out the depression. Polar conditions were replaced by hot arid desert and an ephemeral lake formed. Nowadays, in good rainy seasons the shallow depression fills with water but evaporation in the burning Namibian sun soon

leaves a hard salt crust. At the southern edge of the Etosha Pan the groundwater in the strongly karstified carbonate sub-surface rocks meets the impermeable clay-rich sediments of the pan and forms an infrequent spring line. Most of the time this is evident just as a series of waterholes and these attract enormous numbers of animals which come to drink every day.

Figure 3. Silicified tree in the “Petrified Forest”.

Before heading for the coast we visited several sites of geological interest. In the Petrified Forest we saw fossil tree trunks up to 30m in length lying in a massive bed of the Etjo sandstones (Figure 3). The perfectly preserved tree trunks, with the smallest details and structures in bark and tree rings mirrored by silica, indicate that these giant trees were deposited and immediately buried so that there was no time for decomposition. The absence of roots, branches and fossil soils and the fact that the trunks are aligned parallel to each other suggests that they were torn up and transported in some catastrophic flood and deposited where they now rest. The trees have been identified as *Cordaites* which covered vast areas of Gondwana about 280Ma ago.

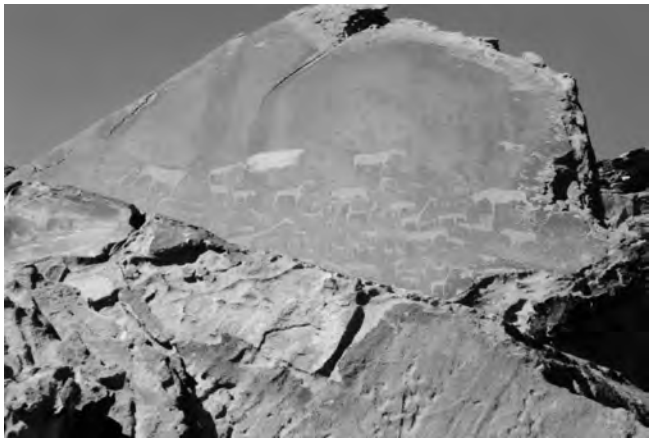

Figure 4. Rock engravings of animals on sandstone bedding planes carved by stone-age bushmen at Twyfelfontein.

We then visited Twyfelfontain which means "doubtful spring"; here water-bearing sandstone overlies a relatively impermeable layer of shale so groundwater can dam up along the shales to create a spring, but this is now very rare. The mostly fine-grained aeolian sandstone blocks have very smooth, flat bedding plane surfaces and on these stone-age bushmen carved images of animals and birds, a lovely example of geology and art coming

Figure 5. The Organ Pipes - columnar dolerite.

together (Figure 4). We also saw blocks containing layers of conglomerate, indicating that at some time there had been rivers in the middle of the Gondwana desert. To round off our mini field trip we looked at Burnt Mountain and the Organ Pipes. Burnt Mountain is a purplish-black rounded hill about 200m above the surrounding rock. About 125Ma ago huge amounts of lava were injected into adjacent shales and the resultant contact metamorphism caused the organic matter to vaporise, leaving a black compact rock. The shales are covered with purple shiny coatings due to the iron and manganese oxides which formed when Burnt Mountain was exposed to the atmosphere. The Organ Pipes (Figure 5) are dolerite which solidified into a group of homogeneously oriented columns with mostly hexagonal cross-sections, very similar to the basalt columns we are familiar with on Staffa.

The Skeleton Coast and the Namib

As we approached the coast we had the eerie view of fog rolling in from the Atlantic Ocean; the cold Benguela Current causes an air inversion as cool winds from the south-west are pushed under the warm inland air. It is this almost permanent fog that gave the Skeleton Coast its name. There are many skeletons of ships that have foundered in the mist.

Figure 6. Welwitschia growing between weathering columnar dolerite.

Our stay on the coast was primarily so that we could visit the Cape Cross Fur Seal Colony where we saw (and smelt) 250,000 fur seals, but we also had a taste of the Namib when we took what is called the Welwitschia Scenic Drive. The Namib is a coastal desert stretching for 2,000km, starting in the Cape Province of South Africa and extending northwards along the Atlantic coast

of Namibia and up into southern Angola. However, it is narrow and in Namibia reaches only up to 120km inland before the Great Escarpment forms its eastern edge. During our scenic drive we had impressive views of the so-called "moonscape" in the Swakop valley: sediments which were laid down 460Ma ago and granite rocks of the Damara Sequence had been deeply incised by the Swakop River. At one point we drove through a huge dolerite dyke formed about 125Ma ago. Because of its resistance to weathering the dark coloured dolerite was clearly visible as a long ridge standing proud of the granite. The "welwitschia" (Figure 6) is unique to the Namib and is a dwarf coniferous tree; the oldest one is over 1,500 years old but is still less than a metre tall.

The long drive across the Namib to the south of the country was amazing. At first we drove through seemingly endless gravel plains with an occasional inselberg rising up out of the surrounding area, the only excitement being a close encounter with a pair of ostriches which tried to become rather friendly. Because there had been exceptional rain there were grasses and flowers in what would normally be bare desert gravels. The gravel road led us through a badland landscape of mica schists to the Kuiseb Pass, down into the deeply incised valley of the Kuiseb River; this represents the northern border of the Great Sand Sea of the southern Namib. It was in this region that two German geologists spent more than two years during the Second World War so that they could avoid internment. As we drove along we wondered how they managed to survive in this extremely hostile environment. We stopped at the Gaub Pass and looked at evidence of the torrential rain which fell earlier in the year. Whole trees had been felled and were piled against the river bridge. Eventually the spectacular Great Escarpment came into view. Reaching a height of more than 1,000m this striking landform runs parallel to the coast and separates the Namib desert from the central highlands. At the end of the break-up of Gondwana there was uplift of the highlands into a bowl-shape and the Great Escarpment represents the western edge of this feature.

Sossusvlei and Sesriem

One of the highlights of our journey was Sossusvlei; "Sossus" means "gathering place of water" and "vlei" means "a hollow which is flooded during the rainy season". Flooding of the vlei happens occasionally, the most recent being in 1997. As it had been very wet a few months before our visit the vlei was a spectacular desert lake. In the past this whole area was flooded and the deposits of silt have formed white clay pans; some of these have been covered in sand but other clay areas are exposed. The evidence of flooding and then years of drought can be seen in the cracked surface of the clay; a few plants which had taken advantage of the rain were still in flower. Arriving early in the morning we had fantastic views of the star dunes (indicating variable wind directions) which looked bright orange in the early light, the colour caused by the iron oxide coating on the sand grains. Some of the dunes rise to 375m above the Tsauchab River bed and are amongst the highest in the world (Figure 7).

Figure 7. Mudflakes beneath star dunes at Sossusvlei.

Figure 8. Weathered marble.

Our lodge for the night was set at the base of a large granite kopje which allowed us close examination of exfoliation, or onion skin weathering, the particular form of weathering that makes the granite boulders so rounded. In the desert nearby we were also able to see another form of weathering that we do not see at home, sand blasting. More apparent on harder rocks as they are more resistant to other forms of weathering, it takes the form of small fluted channels all over the surface, gouged out by wind blown sand. We saw it on the surface of dolerite and an attractive marble (Figure 8).

Figure 9. Sesriem Canyon.

Before leaving the area we visited the Sesriem Canyon through which the Tsauchab flows (Figure 9). The canyon owes its name to the early travellers who came this way. To reach the water with a bucket it had to be attached to six lengths of leather rope (*ses rieme* in Afrikaans). About 30Ma ago, in the middle of the Tertiary, the area was covered by thick desert sands which formed the Tsondab Sequence. A change from arid to semi-arid conditions allowed rivers to form and the Tsauchab transported erosion materials and dissolved limestone from the nearby mountains and deposited gravels and conglomerates on the sand in fans at the foot of the Great Escarpment. About 2Ma ago there was a drop in

sea level due to the glaciation in the northern hemisphere; the resultant increase in gradient to the ocean encouraged the Tsauchab River to cut down into the gravels and conglomerates. The canyon is only 30m deep and about 3km long and there is an easy walk down into it; it was like walking through the pages of a geology book as we were able to see the geological history in the canyon walls; there were distinct changes from coarse conglomerates to fine sandy layers from which we could deduce the changing load capacity of the river as strong water flow changed to weaker flow due to changing rainfall patterns.

On our journey to Keetmanshoop we had magnificent views of the South Namibia Escarpment extending for 100km from west to east, exposing a cross section through the Nama Sequence (Cambrian in age) and the overlying Karoo rocks.

Our overnight stop allowed us to examine a strange looking plant,

Figure 10. *Aloe dichotoma*, (Quiver Tree) growing on dolerite.

Aloe dichotoma, commonly called the quiver tree. It got its name from the fact that the bushmen used the tough but pliable bark for making quivers for their arrows. This plant is characteristic of the very hot, dry parts of Namibia and seems to occur mainly on dolerite or basalt, the dark rock absorbing a lot of heat. The plant can grow in groups and we visited the Quiver Tree Forest (Figure 10); here the dolerite rocks have weathered into blocks perched on top of each other and look as though they have been deliberately placed there, hence the name Giants' Playground. The forest was declared a national monument in 1955 and the biggest trees there are between 200 and 300 years old.

Fish River Canyon

Figure 11. Fish River Canyon

The final highlight was the visit to Fish River Canyon – second in size only to the Grand Canyon (Figure 11). It was awe-inspiring to look down at the river 550m below. The canyon is 161km long by 27km at its widest and it is possible for the very fit and hardy to walk a 90km route through it, taking about five days. It all started about 350Ma ago with graben formation although the oldest rocks exposed, belonging to the Namaqualand Metamorphic Complex, are more than 1,000Ma, some of the oldest rocks exposed in Namibia. The Gondwana glaciation 300Ma ago caused further development of the canyon and the breakup of Gondwana with its associated isostatic uplift allowed the river to erode down to its present depth.

Near the canyon, on the surface of an exposed dolerite dyke, we were able to examine more exfoliation, forming what are known locally as dolerite roses, the peeling layers looking very much like petals.

Of course, in fourteen days we could not visit all the sites of geological interest; we did not get to see the Hoba Meteorite which is the largest single meteorite on earth being nearly 3m in length and weighing about 55 tonnes.

Namibia is a country of superlatives: the oldest desert, the second largest canyon, the highest desert dunes. It has clearly visible rock formations and beautiful landscapes and is well worth a visit.

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Authors

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Patagonia Field Trip 2001

Anne Burgess, Mike Bell & Fred Owen

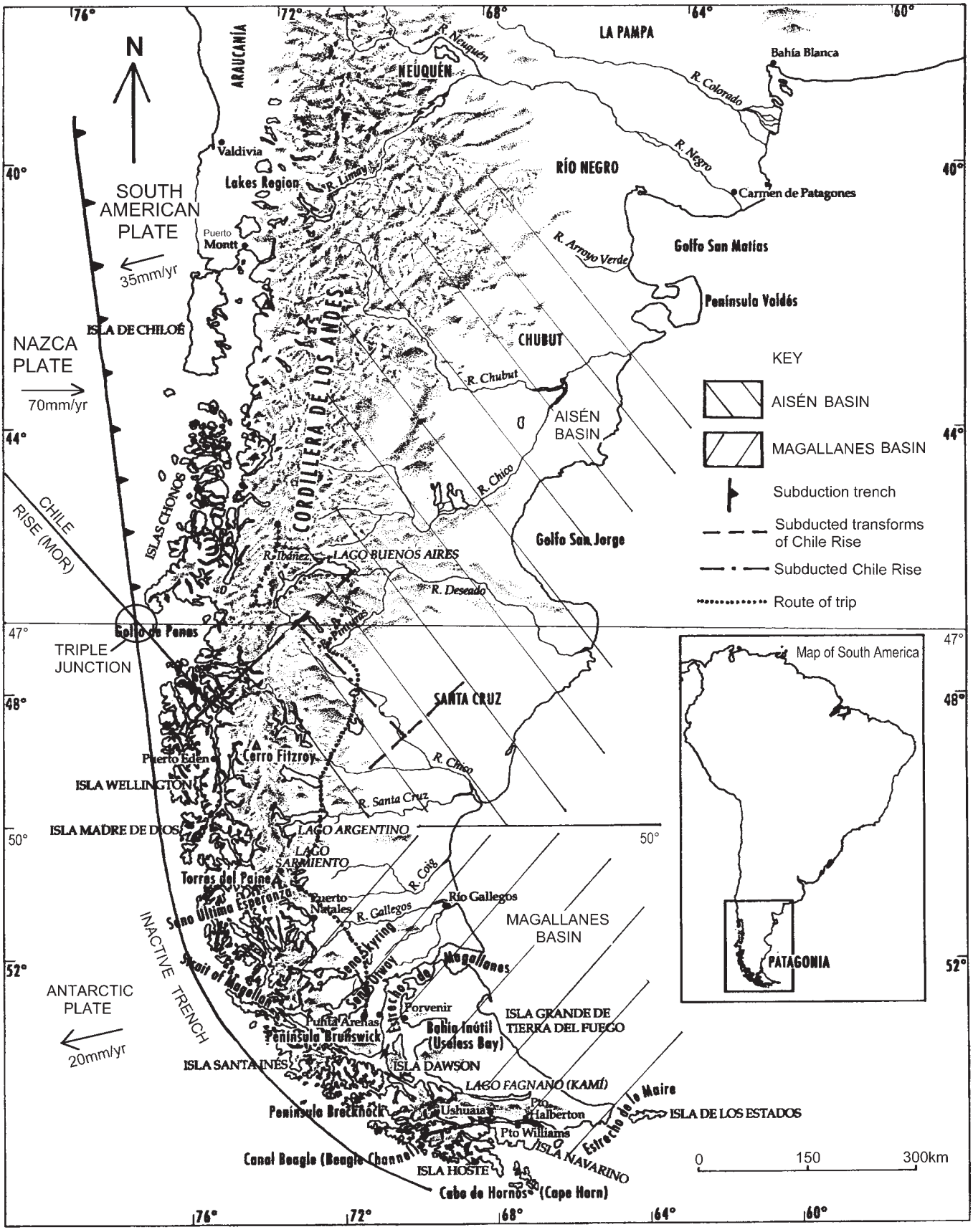

Figure 1. Map of Patagonia: Broad tectonics.

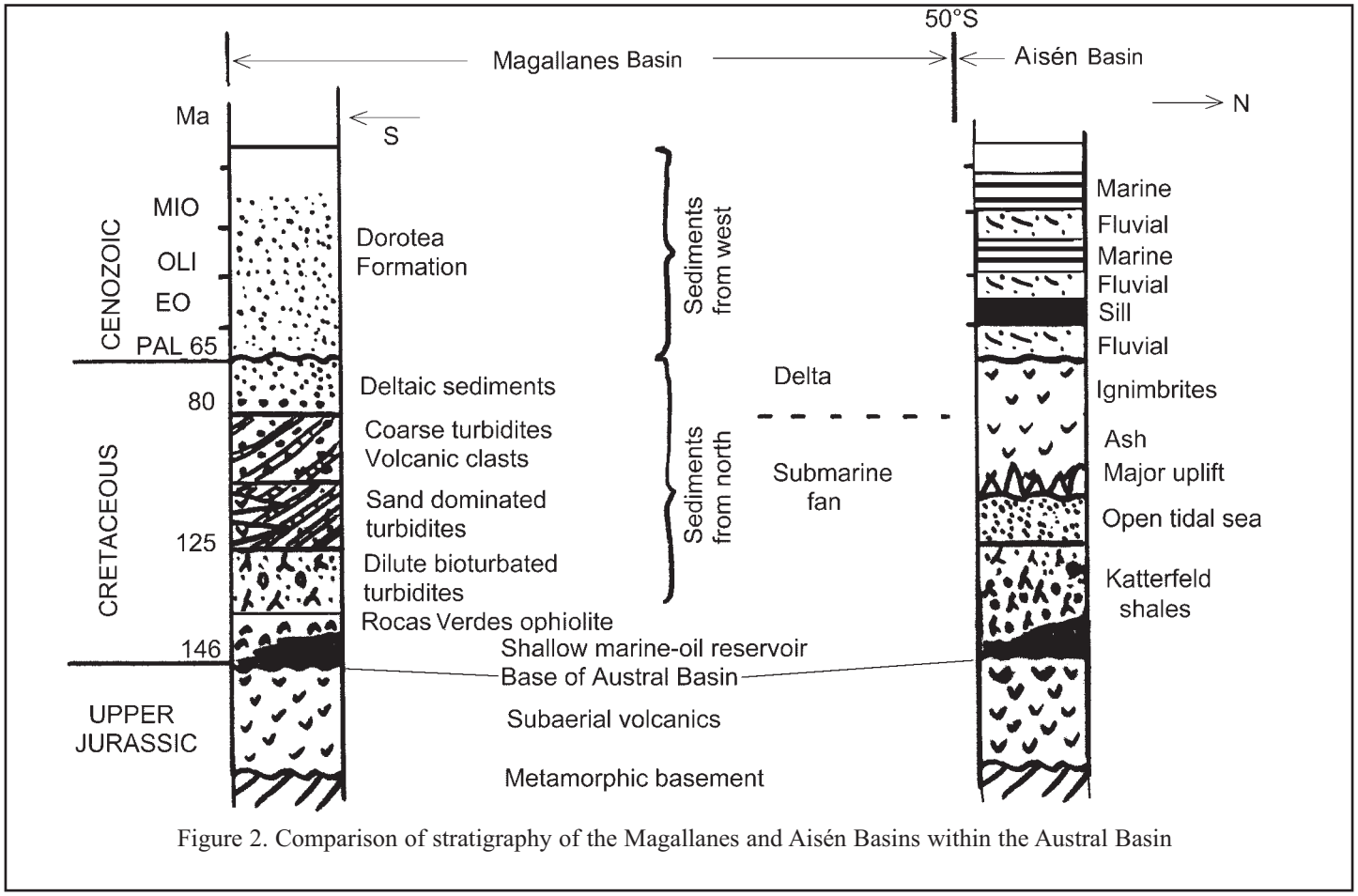

Figure 2. Comparison of stratigraphy of the Magallanes and Aisén Basins within the Austral Basin

In March and April 2001 a group of 18 Open University students, ex-students and relatives undertook a ten day field trip to Patagonia in southernmost Chile and Argentina. The leaders were Mike Bell, OU geology tutor and lecturer at the University of Gloucestershire, and Manuel Suarez, Director of Regional Geology in the Chilean National Service of Geology and Mining. Mike has made a lifetime's study of the geology of the Andes and for the past 10 years Manuel has directed a major project in this remotest corner of South America, producing the first detailed geological maps of an area the size of Wales.

Our first taste of the huge distances involved was the 13-hour flight from Madrid to Santiago, where we assembled for the final flight, which offered splendid views of the peaks, lakes and ice-fields of the Patagonian Andes. At the windswept airport of Punta Arenas, the second most southerly city in Chile, we were met by Manuel, his assistant Pituso, bus owner-driver Don Sergio, and assistant driver Javier.

Before we get into the excitement of the geological features we saw, a few words about the tectonic setting underlying them and the outline stratigraphy will be helpful.

Tectonic Setting of Patagonian South America

The South American continental plate, moving westwards at *ca* 35mm/yr, extends from the mid-Atlantic ridge in the east to the deep ocean trench off the Pacific coast of Chile in the west. The west continental margin abuts two ocean plates forming a triple junction at 74°W and 47°S; north of 47°S the Nazca Plate moves eastwards at 70mm/yr thus subducting 105mm/yr of oceanic crust beneath the South American Plate. South of 47° latitude the Antarctic Plate now moves *ca* 20mm/yr to the west in the same direction as the continental plate so subduction of this plate has ceased. This happened 15Ma ago. The contact between the Nazca and Antarctic plates is a spreading ocean ridge with numerous transforms, known as the Chile Rise. Patagonia extends from about 40° to 54°S, so oblique subduction beneath the South American Plate in Patagonia has had a significant influence on its geology. Figure 1 shows the juxtaposition of the plates.

Outline Stratigraphy

The subduction started to form the Andes *ca* 180Ma producing a magmatic arc of mainly stratovolcanoes in the west and a large subsiding foreland basin to their east, known as the Austral Basin. This basin is further divided into two at 50°S, with the Magallanes Basin to the south and the Aisén Basin to the north (Figure 1). Subsidence started in the Upper Jurassic with the deposition of subaerial volcanics and a shallow marine, oil bearing shale, known as the Springhill Formation.

However, at the start of the Cretaceous the sediments developed in quite distinct ways as demonstrated by their stratigraphy (Figure 2).

Our trip started in the south of the Magallanes Basin at Punta Arenas. We travelled northwards to cross into the Aisén Basin, just north of El Calafate and we end our excursion at Coyhaique, just north of the influence of the Chile Rise (Figure 3).

Patagonia comprises the mountains, fiords and islands of the Chilean Andes in the west and the broad, desolate basin plains of the Argentinian pampas in the east. The national border between the two countries follows the Andean watershed. The notoriously bad weather is also strongly divided into a wet and snowy west-

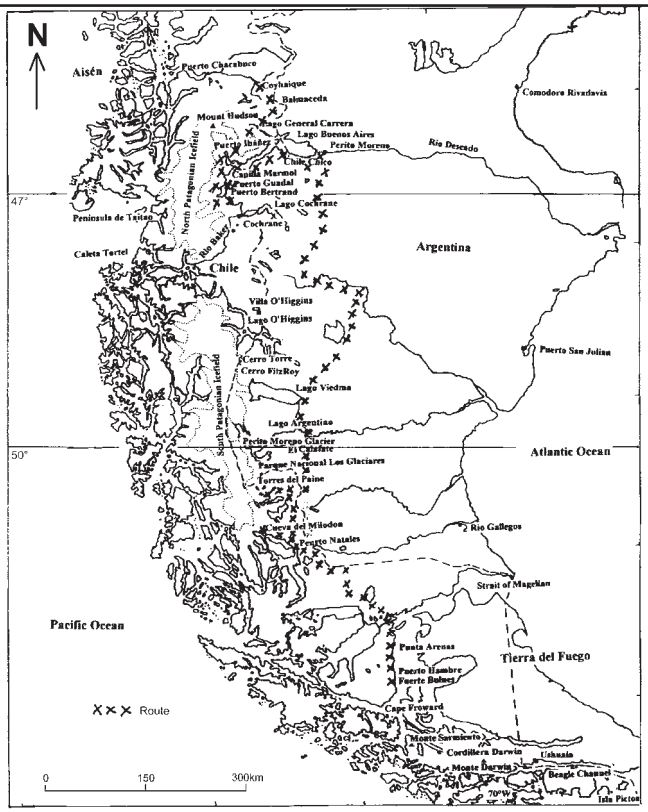

Figure 3. Route and places visited.

ern zone where the constant winds are forced up over the mountains and a rain-shadow desert in the east. These geographical subdivisions are a direct product of geological processes, as the oceanic plates of the South Pacific have been subducted beneath South America over the past 180Ma. The regional geological basement consists of continental crust of strongly deformed Palaeozoic metamorphic rocks. These are intruded by the granites of the Patagonian batholith to the west, and overlain by Jurassic volcanics and a thick succession of Cretaceous and Tertiary sediments in the Austral basin to the east. The sediments have been folded and thrust towards the east as a result of buckling of a shallow succession of sediments on the edge of the foreland basin from compression between the two plates.

Figure 4. Fuerte Bulnes, Straits of Magellen and monkey puzzle tree

The Field Trip

Sightseeing as well as geology was on the agenda and our first excursion took us to the end of the road (literally!). The historic site of Fuerte Bulnes is the furthest south point that is reachable by road in the entire American continent (Figure 4). Nearby we noted deformed shales on the beach beside the tiny cemetery where a large white cross commemorates Pringle-Stokes who committed suicide while captain of HMS Beagle. His place was taken by FitzRoy, best remembered today for his links with Charles Darwin. Back in Punta Arenas we tried the traditional Chilean apéritif, pisco sour, and some of us tried congrio (a firm-fleshed white fish), which we think might be conger eel.

Next morning, after a brief walk around Punta Arenas, we set off to see the Magellanic penguin colony at Seno Otway, only to learn that the penguins (sensibly!) were all sheltering in their burrows from the ferocious Patagonian wind. Pituso and Javier produced the first of the memorable daily picnic lunches from the pick-up accompanying the bus, and we drove on across the wide expanses of the steppe to reach Puerto Natales at dusk. On the way we stopped to examine the spoil from an open-cast coal mine, with evidence of much pumice from volcanoes to the north and a volcanic plug with impressive columnar jointing; we also saw our first rheas (large ostrich-like birds) and black-necked swans (Figure 5).

Figure 5. Black-necked swans.

Next morning we made for the Cueva del Milodón (Figure 6), a cave where the remains of a 10,000 year old giant sloth were discovered just over 100 years ago. An intriguing aspect of the mylodon is that bones and skin have been found in association with the skeletons of the earliest Indian inhabitants. It seems likely that these and other animals were hunted to extinction. We were more interested in the geology of the Cretaceous deep-sea fan conglomeratic turbidites. In the deep cave, eroded by wave action

Figure 6. Cueva del Milodón

Figure 7. Flock of sheep with the granite spires in the background.

at the edge of a long-vanished lake, we found sole marks, and the pebbles in the conglomerate showed evidence of compaction and imbrication. We thrilled at the sight of condors soaring overhead before continuing into the mountains towards the Parque Nacional Torres del Paine, icon of Patagonia. At a stop to marvel at and photograph the view of the towers from a distance we were fortunate to capture pictures of an isolated estancia and its nearby flock of sheep (Figure 7). We were also able to forage among the roadside shales and find our first fossils, identified by Mike as the bivalve *Inoceramus*. As we approached the park we were able to view the spectacular spires of granite, topped by the layer of black shales into which the cream coloured granite had intruded (Figure 7). As we entered the park we encountered a herd of guanaco (Figure 8), large camel-like herbivores. Our accommodation was in cabins reached by a boat across the Río Serrano.

Figure 8 Guanaco.

Next day dawned disappointingly grey and overcast. After a visit to the exhibition in the park headquarters we walked to the Lago Grey viewpoint where, surrounded by icebergs, we were able to see the distant Glacier Grey, from which the icebergs had calved

Figure 9. Icebergs on Lago Grey with glacier in background.

(Figure 9). Next stop was the Salto Grande, a large waterfall on the short river draining Lago Nørdenskjøld from Lago Pehoé. It is surrounded by crumbling black shales and it is hard to understand how a waterfall has been formed in such soft rocks. Finally, passing the perversely named Lago de los Cisnes (Swan Lake) with its population of flamingos, not swans, we descended to Lago Sarmiento where the shore is encrusted with weirdly shaped calcitic deposits, probably formed by crystallisation from the water cast up by waves from the extensive lake. We noted that at higher levels it was the vertical face of the underlying strata which were covered by the calcite.

The following day we crossed the frontier into Argentina and drove on to El Calafate. Unfortunately the border formalities were lengthy and slow on both sides, and the drive itself was long (some 400km of mostly muddy roads), so by the time we arrived it was too late to carry on to the Perito Moreno Glacier, two hours drive further, as planned. Don Sergio, faced with a long drive the following day, was understandably reluctant to add another 160km, but some of the party felt that the glacier was to be a highlight of the trip and were equally reluctant to forego the visit. The leaders came up with the inspired solution of hiring a local coach for the trip to the glacier.

Figure 10. Perito Moreno glacier and treeless rim at sunrise.

We set off at 6am next morning and reached the glacier just as the sun was catching the snowy peaks on a clear, frosty morning (Figure 10). We were very glad that we had not gone there the previous afternoon when the light would have been much less dramatic. We saw and heard the crashes as large chunks of ice split from the face of the glacier and tumbled into the lake below. We noted from the evidence of a treeless rim on the shore of the higher lake how the glacier periodically dams the lake, forcing the water level on that side to rise by anything up to 20m.

Periodically the difference in pressure causes a sudden break through the ice, which results in a massive, life threatening surge of water down the normal river outflow region. A local graphic depicts this perfectly (Figure 11).

We arrived back in El Calafate at 11am, transferred to our own bus, and set off north for the nearest hotel, 610km away at Perito Moreno, where we arrived more than 12 hours later. Soon after leaving El Calafate we moved geologically from the Magallanes into the Aisén Basin.

The road is unsurfaced and there had been heavy rain, so for much of the way there was deep mud making the driving slow and dif-

Las rupturas
¿por qué?
El frente del Glaciar Moreno avanza hacia la península de Magallanes
Al cerrarse el desagüe del Brazo Rico, éste aumenta el nivel de sus aguas.
La gran presión del agua sobre el hielo provoca la ruptur
este dique natural

Figure 11. Local graphic of ice dam and break-through.

ficult (Figure 12). On the way, those in the front seats saw an armadillo and when we stopped to clean the mud out of the bus's air filter we found that we were in a bed of giant fossil oysters. During the whole day we counted six other vehicles on the entire route (the main north-south road in the region) and we saw at most a couple of dozen houses. When we arrived at our rather indifferent hotel at about 11.30pm, we were too tired to care about the holes in the sheets or the imminent collapse of the bathroom ceiling!

Figure 12. The muddy main road with our life support truck.

The following day was much easier. We crossed back into Chile at another slow border crossing, including foot-and-mouth disinfection, then spent some time just above the little town of Chile Chico examining a road cut. This was in softish strata of varved lake deposits with interesting structures including tiny slumps and huge dropstones, faults and thrusts. We lunched at a viewpoint above, surrounded by Jurassic ignimbrites. Our intention to visit a traditional farm was frustrated by the closure of the main, and only, road for an indeterminate number of hours, while the road crew cleared up the debris from blasting to improve the road. We examined the surrounding volcanic rocks and some travertine deposits (Figure 13), observed the terraces marking at least five former levels of the lake, and generally lazed in the sun enjoying the views. The enormous lake occupies a deep valley scoured out by Quaternary glaciers. It is the second largest in South America and is known as Lago General Carrera in Chile but changes its name to Lago Buenos Aires in Argentina. Eventually the road was reopened and we carried on along a precipitous cliff section

Figure 13. Travertine.

named the Pass of the Keys to our super new hotel set right on the lake shore at Puerto Guadal, with a splendid view including Monte San Valentin, the highest in Patagonia, sitting astride the Chile Rise. It has been conjectured that this might account for its prominent height!

Next day was spent looking at the spectacular local geology. The first locality, with an array of interesting features, was a small hill set on top of the uppermost lake terrace, with fossiliferous marine shales of the Guadal Formation thrust eastwards over the fluvial San José Formation. These Cenozoic beds lie unconformably on the Jurassic ignimbrites and are intruded by a sill. Many a gastropod, bivalve and oyster found its way into pockets and bags. The woods around the hill were full of noisy, green Austral parakeets. Less welcome were the extraordinarily irritating sharp-edged seeds of one particular plant, which clung persistently to our clothes and worked their way uncomfortably inside!

To the east of this hill was a major fault which had thrust the metamorphic Carboniferous basement over the Jurassic volcanics and Cenozoic strata. This fault runs east-west down the southern shore of Lago General Carrera. Manuel explained that this 'small hill' is interpreted as the western limb of a 60km wide monocline having a N-S axis.

After a barbecue lunch at the hotel, we went down to the second locality on the shore to examine the curious Palaeozoic phyllites of the basement. These displayed at least four phases of deformation, with quartz rods and small-scale folds, faults and thrusts.

Reluctantly leaving Puerto Guadal, we drove round the western end of the lake, noting on the way that the original drainage pattern eastwards to the Atlantic from the lake had been changed by ice or moraines damming the natural outflow, creating a gorge leading west into the Río Baker and ultimately to the Pacific.

We spent the morning on the lake shore, taking it in turns to make the half-hour boat trip (the boat only takes five passengers) to the spectacular Catedral de Marmol (Figure 14). These marble rocks have been eroded by the lake waters to form a complex and beautiful series of caves and tunnels resembling cathedral arches. Whilst exploring the lake shore we identified perfect examples of chevron folds and a contact between metamorphosed igneous and sedimentary rock.

Leaving the lake, the scenery altered as we entered the deep gorges of the granite batholith, and climbed to the watershed. At

Figure 14. The eroded arches of the Catedral de Marmol.

the top we stopped to view woodland devastated by the 1991 eruption of nearby Mount Hudson. In some places the ash has almost buried the fences leaving only five or six inches of posts protruding through the surface.

At one location the horizontal ash layers could be seen lying on top of the foresets of a prograding lacustrine delta fan (Figure 15). The eruption had enormous economic consequences because it buried the water sources and the grass on the pampas beyond, making it impossible to continue rearing livestock.

Figure 15 Volcanic ash atop lacustrine delta fan foresets.

From our final base in Coyhaique, the capital of the Aisén region, we first descended into the batholith to examine some of the 100Ma old granites, in which we found numerous gas bubbles known as miarolites, demonstrating that this particular granite had been formed high in the crust. The next stop was a road cut in black shales of the Katterfeld Formation, intruded by a parallel swarm of basic dykes, indicative of crustal extension (Figure 16). At the final locality we examined sediments on the slope of a Jurassic volcano, including peperites, debating vigorously whether or not the breccia could be fitted together like a huge jigsaw.

Figure 16. Black shales of the Katterfeld Formation intruded by basic dykes.

The most recent geological features seen were the gravel levées deposited by the flood of a hillside river in heavy rain last year (Figure 17).

Back at the hotel, we enjoyed a final grill incorporating unusual items like cows' udders (!) and presented gifts of appreciation to Don Sergio, Pituso, Javier and of course Manuel and Mike.

Figure 17. Gravel levées from a recent flood.

Looking back, some of us were expecting something rather different from what we actually saw. For a start, we never got our hands on, nor identified, any andesite at all! The distances were much greater than we had ever anticipated, perhaps because the maps most easily available are on a scale of 1:300 000 or greater, so places look much closer than they are. After over 2000km of unsurfaced roads (we wondered why gravel roads always develop transverse corrugations?) we had had enough of travelling. However, the reality was very varied, with everything from splendid metamorphics through all kinds of igneous rocks, deep-sea, shallow marine and terrestrial sediments to glacial landforms. Manuel spoke of doing a follow-up, concentrating just on the Aisén region, in a few years' time. Some of us have started saving already.

Branch reports

East Anglia

Our first event of the year was the Day of Talks and AGM. This was excellent after a suitable venue was found. The original place was cancelled due to decorating! Many thanks to Pi Research for allowing us to use their boardroom and kitchen facilities. Talks were given by Dr Hazel Rymer on Volcanoes, John and Sandy Colby on Aerial Images and Richard Pusey on Antarctica. Then everything was cancelled due to foot and mouth, including the visit to Bradgate Park for the second time (first time due to no petrol). Several people assumed that all trips were cancelled so due to this misunderstanding the trip to Sizewell Nuclear Power station didn't go ahead.

Two trips for the early summer were hurriedly arranged to accessible sites. A joint trip with two other societies for an evening walk on the Industrial Geology of Ipswich Docks was led by Bob Markham. Walton-on-the-Naze was revisited on the same day as the visit arranged for Rockwatch.

Autumn arrived and the Branch has had two very successful trips. A day visit to Upware Pit led by Dr Simon Kelly was very well attended and many fossils were found in the limestone reef. Dave Green led a weekend trip to the Malverns and Cotswolds. We saw interesting rocks, with a mix of Pre-cambrian sediments and fossils, picturesque sites and had a long walk on Saturday. The Malverns were the place to be as it was the only dry area in the country. Sunday's rocks were interesting but the view - well let's say visibility was very limited. The rain fell just as we entered a clay pit, but the fossils were so numerous that I don't think anyone minded. The year will finish with a trip to Winterton in December led by Richard Newman; this is a combined geology and nature trip as we hope to see seals.

Wendy Hamilton

East Midlands

The year began with our AGM, which saw a change in the committee, with myself becoming Branch Organiser, Carol Warcup as Secretary, and Don Cameron taking the new position of Newsletter Editor. Of the other members, Bernadette King remained as Treasurer, Rob Tripp as ordinary member, joined by local lecturer Clyde Hinton.

John Colby had stood down after eleven years and, following the AGM, this occasion was celebrated with a 'This is your Life' style look back at the highs, lows and comedies of the years that John and Sandy had looked after the East Midlands Branch.

At the start of the academic year I visited some of the local S260 Tutorial groups, together with Don, to do some recruiting and it was gratifying to see the support given by the Tutorial staff to the Society.

The year's events began with a well attended indoor meeting, a lecture given by one of our own members, Dr Sid Burdon. Sid spoke on 'The Alteration of Granite to Greisen', looking at the Grainskill outcrop on Skiddaw, the area he studied for his Doctorate.

The first outdoor meeting was our Basic Geology day at the National Stone Centre, a chance for the students of S260 to study their subject in the field. This proved to be a good choice of venue as most of the country was closed due to Foot & Mouth. The morning was spent examining faults, fossils, dips and strikes. The afternoon was given over to looking at the Millennium Wall, a chance to study rock types from all over the country.

Foot & Mouth caused the cancellation of our gold panning trip to Wales and the postponement of our planned visits to Bonsall Moor and Gunthorpe Weir; luckily all our other events were unaffected, being mainly sited in quarries. At short notice, because Bonsall Moor was out of bounds, Carol Warcup stepped in and led a trip round Bedford to look at the building stones of the town. After an interesting morning walk, where we managed to see stalactites forming on a modern building, we spent a sunny afternoon at Irchester Country Park. The old Ironstone mine here provided an ideal introduction to the Jurassic of the area in preparation for our visits to Ketton and Ancaster Quarries later in the year.

In June we visited the White Peak Observatory at Wirksworth. It was a cloudy night but this did not prevent us from having a fascinating evening led by the enthusiastic Rod Tippet. Rod explained how he built the telescope from scrap materials, and the problems of siting observatories the world over. Eventually the clouds cleared and the moon was in our sights. I left at midnight, I have no idea how long the others stayed!!

In July we were to pay a visit behind the scenes at the National History Museum, sadly this had to be cancelled due to lack of support.

The visits to Ketton and Ancaster Quarries followed in August and September. The Ketton Quarry trip was led by Dr Alan Dawn from Stamford, and will be remembered not only for the huge volumes of mud we dragged round on our boots and cars, but for the finding of a near perfect echinoid complete with spines and in an almost life position. This was later identified as *Acroselenia*, and is now in Leicester Musuem. The results of faulting had left almost all the middle Jurassic succession from the lowest part of Lincolnshire Limestone to the Oxford Clay visible to us around the quarry. The Ancaster Quarry trip was led by Dr Graham Lott of BGS and we saw the Lincolnshire Limestone, which is quarried here as Ancaster Stone, and the overlying Rutland Formation.

October saw the running of the Bonsall Moor trip, organised by Clyde Hinton, which had been postponed earlier in the year, which certainly proved worth the wait. Harry Briggs led us round the area that Sir Archibald Geikie had covered when explaining geological mapping to H H Arnold Bemrose (a leading local dignitary and keen amateur geologist) during the years of 1894, 1907 & 1910. Bonsall Moor has long been a favourite trip of this branch, but Harry managed to show it to us from a completely different angle as he included much of the volcanic sequence as well as the metal mining history and mineralisation.

The branch dinner was poorly attended in 2000 so this year we changed the timing in the hope that more people would come along. The event was moved from February to November but attendance was even worse – four committee and two members.

Snowflake (surely the wrong name with the weather being warm and sunny – one suggestion was 'Autumn Tints') was in Bridlington this year as a DIY trip with notes from previous trips and guide books, giving a chance for the participants to contribute to the itinerary. Saturday saw us keeping fit by walking, or was it climbing? up and down the various sections from Sewerby to Flamborough Head, examining the chalk, its folding, faulting and fossils and the overlying glacial deposits and erosional features. Highlight was the collection of Garnet Sands – its beauty only brought out under the lens. On Sunday, we decided to visit the Speeton section of Filey Bay where there is an unconformable junction between the Jurassic and Cretaceous, overlain by tills. Some interesting fossils, erratics, jasper and jet fragments were uncovered and we marvelled at the erosion of the coast, which has brought down a great deal of landslip material over the exposures, before lunching and heading home.

I would like to thank everyone who helped to make this year work so well. With virtually a new committee, it proved a very interesting challenge to all.

Glynis Sanderson

East Scotland

This year's report is sadly short because 2001 has been a memorable year for all the wrong reasons.

At our AGM in January we were privileged to have as our guest lecturer Professor Donald B McIntyre who showed us some of the localities and material he worked with during several years in California.

As a result of the outbreak of foot-and-mouth disease, the programme of field trips did not take place as planned. Our April trip to South Queensferry and our June weekend in Bute both had to be cancelled because of difficulties with access over farm and estate land. It was par-

ticularly disappointing that the latter estate lifted the restrictions only days after we had taken the decision to cancel the trip to Bute. Unfortunately the intended leader had made alternative arrangements in those few days and was no longer available to carry out the trip.

The next planned trip, to the Pentland Hills, was replaced by a trip to Yellow Craig and Cheese Bay led by Professor Euan Clarkson and Mrs Cecilia Taylor. This is a very varied coastal section with something for everyone, from lava lovers to fossil freaks.

Our joint field trip to Comrie with the West of Scotland Branch also fell by the wayside because the leader was obliged to go to Greenland, leaving on the very day of the proposed field trip.

However, the weekend trip to Cromarty in anticipation of the 200th anniversary of the birth of Hugh Miller was a great success. As well as the shore sections described by Miller, where many of his specimens were collected, we toured the town and saw several sites associated with Miller, including the gravestones he carved during his time as a stone mason with their characteristic fluted edges. Visits to Hugh Miller's cottage and the Cromarty Courthouse were also included and talks on the life and times of Hugh Miller. Our thanks go to leader Dr Lyall Anderson, who even brought some of Miller's original invertebrate specimens for us to admire, to Martin Gostwick of Hugh Miller's Cottage, David Alston of Cromarty Courthouse, Jenny Gunn of the Cromarty Centre and our own Angus Macpherson.

The final field trip of the year has also been postponed indefinitely for a combination of reasons including difficulty of access to some elements and the Branch (and event) Organiser being in danger of having to travel to Russia at that time.

I would, of course, like to thank the Branch Committee for their support throughout the year: Jenny for editing the Newsletter, Angus for looking after the funds, Doug for gathering names for events and keeping track of them and Paul for copying and despatching the Newsletter and attending meetings on my behalf. And finally, thank you to the members who participated in the field trips.

Anne Burgess

Gogledd Cymru

Forging the Links

This year has been a strange one. We began the year with the terribly sad and shocking news that Geoff Willett, our newsletter editor and a very active member of our branch, had suddenly died and he was remembered at our AGM for his contributions to our branch.

At our AGM, we were given a fascinating talk by John Church on the formation, development and growth of Robertsons, a major player in geological research, based in North Wales). We then, as with every other branch, could do no more than watch as Foot and Mouth disease wreaked havoc causing many field trips to be postponed, called off or rapidly altered at extremely short notice. Our weekend trip with Liverpool Geological Society to Aberystwyth fell foul of this as did our trips to the Lleyn Peninsula and Nant Ffrancon, both of which were replaced with town trails. It was disheartening that, at the height of the Foot and Mouth crisis, when we had to substitute some of the planned trips with Town walks and museum visits, one so interestingly led by Willy Jones to Wrexham and another led, but nowhere near as adeptly as our other leaders, by myself to Llangollen that we did not get the support that we had hoped for. However, things can only get better! Many of our leaders are willing to give their time again and at least we already have much of next year's programme in order!

And things have got better! June saw us once again (with some very cold weather) visiting Hilbre Island under the expert guidance of Rob Crossley, who was also our leader for a fascinating trip to Anglesey to look at the Carboniferous deposits in Lligwy Bay in August. October saw us following an excellent town trail around Knutsford led by Fred Owen (which Fred needs to be encouraged to publish) and following his trail around Styal Country Park; both of these are under the flight path for Manchester Airport and it was a little disconcerting when examining Portland stone window ledges to see jumbo jets looming out of the background! I am happy to say that all these trips were successful and attended by an average of twenty people.

As well as trips arranged by ourselves, many of our members have been involved with events organised by other branches and societies. In February we contributed a display of our events to the Wrexham Science Festival (along with NWGA and both RIGS groups) which was so successful that the organisers would like the main emphasis to be on Earth Sciences next year. July saw several of our members attending the symposium in Dublin. We also had a presence at the National Eisteddfod in Denbigh during August. In September we, along with the North West branch, supported a well attended S260/S269 revision day in Chester. In November, Gogledd Cymru branch attended the annual GA reunion in Liverpool, where I am ashamed to admit that I did some 'networking' and have 'bullied' several people into leading future trips! Throughout the year many of our members have been attending lectures organised by the NWGA (in either Conwy or Wrexham) and it is thanks to the efforts of Rob Crossley and Fred Owen that this is so successful. I also know that Fred is very involved with Manchester GA, Sue Hughes is involved with Shropshire GS, Sue Brooks is involved with Gwynedd and Ynys Mon RIGS and I am involved with NEWRIGS and I apologise to anyone I may have missed. These liaisons have worked extremely well and have ensured that we can bring many opportunities for members in our area to get as much geology as possible. It is something that we all are keen to continue and develop in the future.

Once again, I need to thank the committee (Alan, Ann, Fred, Sue and Tony). I would especially like to thank Ann Bunning who so readily stepped in to take on the role of newsletter editor (no mean feat, I can assure you) and Tony James who was slightly coerced into joining us! My thanks also go to Fred, Sue and Rob and all at NWGA, as well as everyone else who has supported and helped us throughout the year. I would also like to thank our leaders and those of you who attended trips and events or contributed to our newsletter; it is always a pleasure to meet you.

Our main aim for next year is to continue to forge and strengthen our links with the other geological groups in North Wales so that we all can have a better understanding of, and more opportunity to study, the geology of our area.

Wendy Owens

Ireland

This has been a strange year for the branch with the tragedy of foot and mouth severely curtailing our field trip programme, but the National Symposium taking place in Dublin was a great success.

Branch membership stands at 45 full and 7 family members which is up slightly on last year. The branch AGM took place in University College Cork on Saturday 17th February with 11 members in attendance. Following the AGM, we enjoyed a great meal in Cork and retired to Crosshaven for the night.

The following day Dr John Reavy took us to look at the Volcanics of Limerick. Starting at Knockderc quarry, we examined a syenite intrusion into lower Tournasian limestone. We then moved on to Nicker church where a basalt lava flow overlies well bedded limestones; we were able to trace the contact from the chilled margin of the basalt and the contact metamorphism in the limestone. At Linfield House there was evidence of columnar jointing in a lava flow or sill. We finished the trip off with a look at the pyroclastics and lavas of the Knockroe formation at Knockroe.

The National Symposium took place in July. I believe that the uncertainty of the foot and mouth reduced our numbers, but the 220 who did attend seemed to enjoy the experience. A line up of top speakers gave interesting and informative talks, and who will ever forget Prof Gordon Herries-Davies after starter talk on the Saturday night. A number of the field trips attached to the Symposium had to be altered due to the continuing worries about bringing people into the countryside, but the resourcefulness of the leaders meant most people were well catered for.

In September Mark Cooper took us to the East Antrim coast. At Minnis we were able to see evidence of mud flows including one which had occurred only days before our visit. The mud flows involve the Hibernian Greensand formation and incompetent clays of the Waterloo Mudstone formation and Penarth Group. Some lovely fossils, both bivalves and ammonites were found on the beach where the mudflows had been worked by the tides. At Garron Point we were able to see some spectacular examples of slumped blocks, seeing the different angles these huge blocks have been rotated one can visualize the sequence of events which has formed this landscape.

It was very unfortunate that we lost most of our field trips this year, but already we have a good and varied field trip itinerary lined up for next year, so I hope to see you all out in the field then.

I would like to thank all our members for their support. I would like to thank all our Speakers who gave of their time and effort to help make the Symposium the success that it was. I would also like to thank all our field trip leaders for their efforts. But I would especially like to thank our branch and symposium organizing committee for the huge efforts they put in; they were Mary Cromey, Maire O'Brien, Phyllis Turkington, Susan Pyne, Bettie Higgs, John Deykin and Michael Andrews. Last but not least, I would like to thank Geoff Cromey for all the work he did for us in the background; this was not seen by most of us but surely made all our lives a lot easier.

John Leahy

London

In January London Branch found itself immersed in the Betics of Spain, a talk given by Paul Grant of RSM, followed by our AGM talk Geowanderings in Tibet given by Sue Hay. February found the Branch introducing the new S260 students to Geology on the beach at Walton on the Naze. The half term break allowed us to play the Eton Wall game with Eric Robinson and an evening talk at Royal Holloway. In March Adrian Rundle kindly opened his doors to the branch for a workshop on Microfossils. April saw the cancellation of field trips due to "soggy quarry syndrome" and the outbreak of Foot and Mouth disease. The weekend trip to Anglesey in May also fell foul of the Foot and Mouth outbreak, though the monthly talk on New Zealand given by Barbara Cumbers lifted the doom and gloom. June swept in and at last we could get out in the field with a visit to Cow Gap and Beachy Head with Rory Mortimer; Brian Harvey's talk about Geology and Society in SE England was informative and as entertaining as ever. July saw several members of the Branch heading over the Irish Sea to Dublin for the Symposium and a great time was had by all, a big thanks to everyone who was involved in the organization of that event. Our monthly talk was replaced with an evening building stones walk around Albertopolis (the area around the Albert Hall) with Eric Robinson. September saw the resumption of field trips with visits to Brookwood Cemetery, and Dorset with Paul Ensom, the monthly talk on Volcanic Disasters Past Present and Future was given by Bill McGuire. The October talk was a do-it-yourself affair with several members of the branch showing slides of places they had visited; a quiz devised by Di Clements and Sue Hay proved very popular with those members who attended. A week's trip to the Naples area with Chris Kilburn rounded off the autumn. November arrived and the winter weekend to the Hunstanton area led by Ivan Finney was great fun though a trifle cold. Louise Thomas of the OU gave the November talk on Silicic volcanoes, Large and Small. Minerals were the focus of the December talk given by Bob Symes. Finally as Branch Organizer I would like to thank the Committee of London Branch for all their hard work throughout the last year, without them such an interesting and varied programme of events could not have taken place.

Sue Vernon

Mainland Europe

Saturday 28 October 2000 – OUGS Mainland Europe officially became a branch of OUGS. Work had, of course, been going on for some time before the inaugural meeting, but now things were official. The festivities started on Friday evening, with a get-together supper for the 10 members from six countries, plus partners, who had booked for the weekend, and continued through Saturday with a field trip to the Kaiserstuhl volcano in S Germany, including wine tasting and picnic at a local beauty spot. The official meeting was held on Saturday evening, opened by a local traditional carnival group, and followed by a celebration dinner. OUGSME, being an international group, elected an international committee, with a treasurer and newsletter editor in France, a webmaster in Belgium, a public relations officer in Austria, a librarian in Germany, and myself, as Branch Organiser, in Switzerland. Due to the nature of the organisation, OUGSME holds VIRTUAL committee meetings from time to time; in fact, without a PC and e-mail, communication would not be as lively as it is.

In June 2000 a branch website was born and an official branch newsletter had also been created and distributed, but this had to develop into its present electronic form. Since 2001 the newsletter has appeared quarterly, containing news, information, articles from members and friends and reports on our first official trip, a week on Sicily exploring Mount Etna.

Catania airport, 19 May 2001: the first trip was underway. 15 participants from Mainland Europe and the UK met for an exciting week learning about Etna and its impact on the people who live in its shadow. Apart from a few teething troubles, the trip was a great success, helped by the volcano itself, which was quiet enough to allow close contact, but active enough to give everyone an insight into its eruptive potential, and I do not think that anyone will forget the nightly display at the summit, with Strombolian activity producing spectacular explosions and a lava flow of several kilometres into Valle del Bove. Our leader for the week was Dr. Boris Behnke, a German resident in Catania, and author of an excellent website with a great deal of information on Sicilian volcanics. OUGSME was included in his report from 25 May 2001, and our link added to his site.

The branch has spent much of the year dealing with organisation. Being as widely spread as we are it proved difficult when we tried to open a Euro bank account. After preparations and promises from the French bank Paribas, they finally pulled out, finding our organisation too complex for their system. The French post office was a second option but, after they demanded I go to the Bordeaux region to sign the papers, we pulled out. The Dresdner bank in Germany provided us with an account for the Etna trip, which worked very well when money was coming in, but proved a nightmare when we wanted to get at our finances, resulting in a three-currency financial statement from our trustee in Munich. I believe a great many of the problems have to do with the transition from national currencies to the Euro, a situation for which the banks seem badly prepared, and it can only be hoped that when Europe makes the change in January, financial transactions will be much easier to handle. At least, at the moment of writing this report, it would seem that we are near to completing the formalities for an offshore account with NatWest, who have been very helpful from the word go, despite the mountains of paperwork involved both for myself and for Mike Gilmore, our very patient treasurer.

A flyer was produced and sent to the OU's region 9 for distribution in Europe, introducing the branch to all with an interest in geology. At the same time we were pleasantly surprised when Paul Williams, from the Earth Sciences staff in Newcastle, contacted us to report that he was setting up a website with useful European contacts. This information is of great help, and OUGSME intends to contact many of the organisations for information, and plans to put together a programme of interesting events for the use of European members who do not have a chance to otherwise participate in trips or lectures.

And so a busy first year comes to an end. Information has been distributed on coming events for 2002, including our AGM in Brussels in February and a trip to the French Jura mountains at the end of July. Preliminary information is also being collected for a possible trip to Santorini and, and..... Ideas abound.

To conclude, I would like to add a word of thanks to my committee, especially Mike Gilmore for his unending optimism and hard work in trying to set up the bank account, despite ill-health, Ann Cripps for the newslet-

ter and Ole Nielsen, who has done a wonderful job in designing and maintaining the website. Also, my thanks go to Mike Molloy in Munich, who, despite not wishing to be a committee member, did not hesitate when asked to take over the financial arrangements for the Etna trip, and who administered our funds with prudence and a great deal of patience in the face of adversity. Without the helpers, OUGSME would not be possible. We now look forward to 2002, with the same motivation which made our branch possible in the first place.

Annette Kimmich

Northumbria

The year began with high hopes. There was a good attendance at the Annual General Meeting, held at the University of Durham, where we were treated to an innovative and interactive lecture by Dr Trevor Morse entitled All Aboard the Plate Tectonic Express: departs South Atlantic circa 500 Ma. This was followed by a social evening in the common room.

The committee had worked hard to organise what promised to be a lively programme of field trips and other events. Alas, alas! Hardly had the reconnaissance for the first field trip to the coast at Amble been undertaken than Northumberland hit the headlines with the outbreak of foot and mouth disease. Such were the problems at the burial site at Widdrington, not far from Amble, that even the trip to the shoreline had to be cancelled in case the prevailing wind blew the smoke across the beach. We lurched on from one event to the next, each in turn having to be cancelled.

In June, our Treasurer Pam Sidgwick felt obliged to give up this task as she was finding herself very busy both at work and at home. Fortunately, Helen Watson agreed to take over. We'd like to thank Pam for her hard work over the years and wish her well in the future.

July and August meant the Summer Schools at St Mary's, and Dr Peter Sheldon asked if we would sell the tickets for the Thursday evening disco – this time held not by OUSA but by OUGS. The funds raised went towards the support of an early warning system for the Nevado del Ruiz volcano in Colombia, in memory of Geoff Brown. Walton Hall kindly sent a photograph of Geoff that was used on a poster to advertise the disco – after all, new students to Earth Sciences may be unaware both of the contribution Geoff made to the department, and of his untimely death. The change of the summer school to a 10-point, assessable course appeared to have put a damper on student activities – they all seemed to retire to their rooms at about 10.00 pm to study!

August was also enlivened by a wedding – that of Penny Nicholson to Robin Widdison; Penny looked stunningly radiant (and Robin didn't look too bad either!) and at the subsequent reception a large gang of OUGS members found themselves talking about a wide variety of things.

We managed our first outing at the end of September – a geowalk around the city of Newcastle upon Tyne led by Dr Steve McLean, curator of the Hancock Museum. At this time the difference between looking and seeing was made apparent – we'd all seen the River Tyne God on the walls of City Hall, but never really looked at the mica schist which clothes the building. We saw a wide variety of granites, the provenance of some of which were known, but perhaps most astonishing was the façade of Burger King – a metamorphosed conglomerate of pink, cream and grey. Steve later took us behind the scenes at the Hancock Museum, where we were privileged to see some of the type fossils of the Carboniferous.

Cold, crisp autumnal weather made the trip to Mam Tor under Chris Arkwright's guidance most enjoyable, especially as the group finally got to know the difference between a cave and a cavern, and there seemed to be a great deal of ooh-ing and aah-ing going on.

The latest event has been our quiz held at the Red Lion in Plawsworth. We started with Helen's music round – much appreciated – but Dave Ramshaw's questions were fiendishly difficult, and Penny's graphic log sequences caused anguish and despair – perhaps this should have been the first round so that the logs weren't viewed through the hazy glow of at least three pints!

The big news of the year is that the north east will be the setting for the OUGS Symposium in 2003. Organisation is now under way with an enthusiastic symposium committee, including Norma Rothwell and Hilary Tatton. The first brainstorming session has been held during which nothing was rejected out of hand – just in case!

Hopefully many of the field trips arranged originally for 2001 will be run in 2002. In the meantime I'd like to thank the committee for their help and support, Pam for her hard work, Helen for taking over as Treasurer and all our members.

Linda Lane Thornton

North West

Our January lectures this year were held at Lancaster University; the subjects were 'Hazards of Volcanoes Under Ice' by Hugh Tuffen (Lancaster University) followed by 'The Life and Times of Richard Owen, a Victorian Naturalist' by Vic Parsons (Open University). The branch AGM was held on a Saturday evening in February and was followed by a dinner at the same venue.

The first outdoor meeting in March involved a morning building stones walk around the Trafford Centre, Manchester where, amongst other things, we were introduced to some very exotic marbles from Brazil. The afternoon found us looking at the marvellous engineering feats along the Bridgewater Canal, including the Barton Swing Roadbridge, Barton Aqueduct and the method of coal extraction at Worsley Delph by using the canal. The day was finally concluded by a visit to the old Astley Green Colliery site where a team of mining enthusiasts are in the process of preserving what was the largest steam winding engine in the country.

A field excursion to Hawaii was organised for April and many NW members together with those from other branches were able to enjoy this experience. Chapel-le-Dale in Yorkshire was to have been our home-based venue for April, but the onset of the foot and mouth crisis meant the cancellation of this field trip at very short notice and a complete reappraisal of our events programme. Along with many other branches, an interim solution came along in the form of a building stones walk and our May field trip found us scrutinising the buildings of Bolton town centre, which proved to be quite a mix of local and imported stonework. The shoreline offered areas that were permissible and the branch visited the Oceanographic Laboratory at Bidston, Cheshire, followed by a look at the glacial sediments and Triassic sandstones of Thurstaston beach in the month of June.

With careful planning and adhering strictly to those areas not affected by the ban, a trip to Clitheroe in July was successfully achieved; the roadside crinoid beds affording us much discussion.The day ended with a visit to the Castle and museum which displayed a geological exhibition of the area. Once more, the sea shore came to our rescue in August when the beach at Heysham provided an interesting mixture of faults and thrusts in the Carboniferous sandstones during the morning, with the monocline in the limestones at Trowbarrow keeping us busy in the afternoon.

At the beginning of September the S267/S268 Geophysics weekend was held in Penrith, Cumbria; a number of the members of the NW branch committee were once again greatly involved in the organisation and support of this event. Later that month we were finally able to run the Derbyshire Mineralisation trip that had to be cancelled owing to the fuel crisis of last year. The events in September ended with a very successful Revision Day held at Chester and, similarly to last year, this was a joint venture with the North Wales branch. Approximately 40 students from a wide area booked for the day to brush up on topics relevant to S260 and S269; all of the students expressed their opinion of its usefulness.

In November, the relaxing of the foot and mouth ban enabled us to visit the Triassic sandstones around Frodsham, Cheshire. Good examples of cross-bedding, grain type etc. enabled us to ascertain depositional environments both aeolian and water lain. This was preceded by a visit to the Daresbury Laboratory where we were shown the type of research being carried out at the synchrotron; its light source being used for many pur-

poses including probing the structure of proteins, investigating the properties of cement and research into cancer and medical problems.

In early November the Geological Association held their reunion in Liverpool; a number of our branch committee members attended with a display to represent our society as a whole and also to interest people in the S260 course. Our field event for November is a morning visit to the Williamson Tunnels. These were built under the city of Liverpool in the 19th century to create work for the unemployed. An afternoon trip to the city centre to look at some special building stones will complete the day.

To round off the year's programme, our final winter lectures will be held in December at Middleton when the topics will be 'The Geology of Patagonia' by Fred Owen and 'Unusual Geophysics' by Steve Truss (Leeds University).

Our current branch membership stands at around 250 with lapsed members being replaced by new ones. We have enjoyed another year of varied, informative and interesting field events which, in an odd sort of way, was helped by the foot and mouth crisis making us do some rather different things. My thanks for another successful year go to the branch committee, leaders, lecturers and all members who have contributed throughout the year.

Alan Diggles

Oxford

The membership of Oxford Branch stands now at about 100 members, many of whom regularly take part in our varied programme of lectures, day trips and weekends away.

There was good attendance at our AGM in January at "The Spotted Dog" near Newbury. This year saw the introduction of a post-meeting talk, when David Maddocks (who represented the NEC at our AGM) regaled us with slides of the geology and wildlife of fascinating and beautiful Namibia. This was followed by our First Annual Dinner.

Our February lecture was given by Dr Peter Skelton at the University of Reading. In his most interesting talk, he used the evolution of Mesozoic molluscs called Rudists to illustrate the concept of preadaption.

In March, the countrywide outbreak of Foot and Mouth Disease and subsequent closure of the countryside had devastating effects on animals, farmers, and the tourist industry, not to mention OUGS planned fieldtrips. Our Branch did as most others had to – we cancelled or postponed, or changed a day in the field for one in a museum, or a building stones walk around town.

Thus our first field trip of the year was to Temple Mills Quarry, in the Great Oolite in Oxfordshire. A small number of stalwarts did some solid work on mapping the quarry floor. The quarry is being considered as a possible RIGS site.

The Society's Symposium, held in Dublin in July, was extremely successful and enjoyed by over 200 members, including about six from Oxford Branch.

In July, John Downes led the Branch on a splendid weekend trip on the Pembrokeshire coast, where we saw *inter alia* the sharp folding of the Ladies' Anticline at Saundersfoot, and another anticline at Stackpole Quay, with the Stackpole Tear Fault clearly cutting through it.

Also in July, we were fortunate to have the guidance of Philip Powell, of Oxford University Museum, on a building stones walk around Oxford, followed by a tour of the Museum itself.

Dr Jill Eyers was our leader on an excellent day trip in September when we explored Combes Quarry (Buckingham) and the Buckingham Sand Pit.

We are grateful to Dr Roland Goldring, University of Reading, for giving – at short notice – the Second John Souster Memorial Lecture in September. His very interesting talk covered his work on the sands and gravels of three Oxfordshire quarries. This proved to be a most appropriate lead-in to our trip with Roland to these quarries about 10 days later.

The Branch now looks forward to early November when we have our last field trip of the year, to be led by Dr Ian Rigby in North Devon and North Cornwall.

Our December talk will be given in Oxford by Dr Dave Rothery on The Geology of Jupiter's Satellites. This will be followed by the Branch's Christmas party.

Our thanks go to the leaders and lecturers who have willingly given their time and services to our Branch events. May I also thank all Oxford Branch Committee members, whose hard work and support during the year contributed much to the smooth running of the Branch and our events, and ensured that 2001 was (despite FMD) a successful year for Oxford Branch.

Madeline Ettlinger

Severnside

We held our AGM in February at the Museum of Wales, Cardiff and were entertained before and after the meeting by lectures given by Dr Jana Horak and Alan Channing from the Museum of Wales. Jana's talk was on the Precambrian Rocks of Wales and Alan Channing's was about his work in the USA looking at modern analogies of the Rhynie Chert of Scotland.

At the end of February our trip was to the United Arab Emirates. This was an excellent trip led by Stephen Howe of the Museum of Wales, Cardiff. It was a wonderful place to go for our winter sun (guaranteed sunshine) and a wonderful country to visit.

March, back to earth and our country where it rains. Dr Geraint Owen did our introductory day for us and took us to Portishead; we had a good turnout and Geraint enthused over the wonderful sedimentary structures seen in the Old Red Sandstone signifying a braided river system.

Although the Foot and Mouth Disease affected some trips, we were lucky that we had booked Linda Fowler to do a Building stones walk around Hereford in April. This meant that we could examine sedimentary, igneous and metamorphic rocks without getting our feet muddy! The weather was particularly cold and wet on that day.

Our original plan for the May Bank Holiday weekend was to visit Brittany to look at the granite. Dr Joe Jennings (ex-National Secretary) did his PhD on the granites there so he agreed to lead a trip for us but, due to member's lack of interest, we did not go. At the end of May we did a combined trip with the Wessex branch to West Quantoxhead and Kilve but I was the only one from Severnside branch that went, although they had a good turn out. June was particularly bad for Foot and Mouth Disease so no trip was arranged.

July was the Symposium - held in Dublin and a few of us had a very good time there listening to some very good lectures. Also in July we had a superb trip to the Gower, led by Prof. Paul Wright. This would have been absolutely brilliant for those studying S338.

Our next trip was a Traverse of the Black Mountain, Carmarthenshire. Dr Geraint Owen of Swansea University led us and we did a classic traverse across the Palaeozoic rocks. Our after exam trip was to the Malverns with Jana Horak - we looked at the PreCambrian rocks there and heard a lot about the geochemistry of the granites. We finished off at Gullet quarry.

Our annual Day of Lectures is being held at the Museum of Wales, Cardiff for a change from our usual venue, Chepstow. We have three speakers, Linda Fowler- our UAE trip, Louise Thomas from Walton Hall on Super Volcanoes and Alan Cuthbertson on Trees of Stone, Men of Iron.

We thank all the leaders who have led some wonderful trips for us and I thank all the people who support the branch by attending these events.

Jan Ashton-Jones

South East

The Branch has about 120 members, mostly from East Sussex and Kent, but several from the Home Counties, Surrey, West Sussex and Essex. We try to hold a varied programme of activities throughout the region and

beyond, but this year's outbreak of Foot and Mouth disease has tested our resourcefulness.

The branch's usual format for the AGM attracted a good number who enjoyed Dr Richard Waller's (Greenwich University) talk on 'Fire and Ice - Journeys in Iceland' and the meal in a local restaurant. We visited the Natural History Museum in March and thoroughly enjoyed the Earth Lab where we were joined by Dr Adrian Rundle. He demonstrated a method to gain all the micro-fossils from a clay sediment and then deduce, using microscopes, the environmental deposition of the clay.

Our early residential May weekend to Pembroke with Dr Gareth George (Greenwich University) was enjoyed by all. His enthusiasm for sediments infected us all, to the point where we may never find an igneous or metamorphic rock interesting again! Despite the restrictions on sites visited Gareth ensured that we saw what must be some of the most spectacular sediments in the UK.

The field meeting to Tankerton and the Long Rock at Swalecliffe on the North Kent coast with Martin and David Rayner had us getting rather muddy and wet. We found many fossils in the London clay including gastropods, crinoids, fish fragments, phosphatic nodules containing crab and lobster remains, vertebrae of various animals and much plant material. Martin showed us part of his extensive collection which included some incredible bird-skull fossils.

Our visit to Darwin's Down House was postponed to June 2002.

The 'Quarry visit' in July involved a guided walk along the Clandon - Albury traverse with Ian Fletcher. For several years he has been involved with Surrey RIGS and, through the London Branch, has encouraged cleaning and conservation of the geological faces at this site. We walked along a cross-section of south-east geology, from Upper Chalk down to Hythe Beds.

Phil Ingham led our Post-exam weekend in Dorset. Sites visited included Tarmac's Swanworth Quarry near Worth Matravers, in Portland Freestone and Sand, where we found parts of the huge ammonite *Titanites*, several *Trigonia* bivalves and the evaporite 'beef' anhydrite (calcium sulphate). The cycles of sedimentation and their possible relationship to Milankovitch cycles, shown in the cliffs at Kimmeridge Bay, provided us with much discussion. The general consensus of opinion, (once Phil had told us) seemed to be that there must have been some other influence involved, due to there being sudden changes of sea-level identified at the end of each cycle. If the changes were solely due to Milankovitch cycles the changes in sedimentation would have been gradual. The impressive cliffs at Burton Bradstock in Inferior Oolite, yielded few fossils, but the honeycomb weathering and associated chemistry provided us with information to deduce the environment of deposition.

Four members represented the Society at the Eastbourne OUSA Conference in May, and supported the display stand. The Branch services were again called upon to man the recruitment stand at the University of Sussex for the SRS103 residential season. This is a highly lucrative way of gaining new members and our thanks must go to those who helped: Heidi Barnes, Roger Baker, Yvonne Cutt, Brian Holyoak, Debbie Tabner, Len Wellington and particularly to Pat Dowling who showed great organisational skills. I am sure that Pat would also like to extend thanks to Norma Rothwell (North West) ex-Chairman and OUSA rep., who was extremely supportive and helpful.

This year we welcomed Nigel Spencer as our new Treasurer who has taken over from Roger Baker. My grateful thanks to Roger for being so diligent with the branch's finances and I look forward to working with Nigel. Vivian Bailey agreed to do the newsletter after Heidi Barnes decided to retire from the job. Thanks to Heidi for all the hard work which she has put into producing information for the branch over many years. I would also like to express my most grateful thanks to our leaders, who give up their time for us, to the participants who make the meetings so enjoyable and last but not least, to the Branch Committee.

Yvonne Cutt

South West

We began our year with the AGM in January. This year saw major changes in Branch Officers: Linda Fowler had to resign as she had become OUGS Secretary and she was replaced by myself as Branch Organizer. Keith Farmer relinquished the post of Treasurer due to ill health and was replaced by Chris Halliday. Keith was then elected as an Ordinary committee member along with Paul Fitzmaurice, Phil Romford and Jane Anderson. The AGM was followed by talks on the Alps by Linda Fowler and the Rift Valley of Tanzania by Mike Mallett. The latter was an interesting follow-up to last year's talk on the Ethiopian Rift Valley by Kate Ferraday.

In February, Linda went on the United Arab Emirates trip led by Stephen Howe. They looked at geology ranging from the Palaeozoic basement to Cretaceous oceanic crust, reefs and fossil beds plus modern desert and arid coastal features. During this month we learned of the death of Keith Farmer, our recently retired Treasurer. He had been an efficient Treasurer and one of our busiest and most reliable members. He has been sorely missed during the year.

March saw our first loss of a field trip due to Foot & Mouth Disease. We had to cancel a morning on Kit Hill looking at the granite, metamorphic aureole and mining remains. The field trip was to have been followed by a talk by Professor Malcolm Hart on Global Warming, a Geological Prospective. However, as Cotehele Estate was completely closed, this too had to be cancelled. Other losses during the year were the S339 weekend in SW Devon and an East Devon field trip with Prof Hart, both of which were planned for May.

Fortunately, Cotehele Estate re-opened with about two days to spare and our planned Open Day was able to go ahead in April. This was later this year to allow students to settle into courses. Attendance was down slightly but this was due mainly to the uncertainty caused by Foot & Mouth. The morning of displays and activities (how can we get so many different specific gravity results for the same rocks?) and mini building stones walks on Cotehele Quay were followed in the afternoon by Linda's tales of the Orient and the United Arab Emirates Trip and a fascinating talk by Bob Thomson on the geology of southeast Australia. This is an area that few of us had any knowledge of and the talk provided us with an introduction to what is an extremely interesting area.

In Cornwall we were reasonably lucky with Foot & Mouth and the Coast Path was soon reopened. In June as the Pre-SXR260 field trip was at Widemouth and did not require access through agricultural land, we were able to provide our annual introduction for those on that course. This year saw about 20 people enjoying the fieldwork at what is fast becoming our favourite site.

We had an extended break for the summer as Mark Anderson of Plymouth University, who was due to take us to the South Hams in September, was called away by other commitments and we were unable to find a replacement. Our next field trip proper took place in October when we visited the Belstone area led by Mike Mallett and Gordon Neighbour. The trip was entitled "Tin Mining on Dartmoor" but we discussed tin, copper and water among other subjects. As Mike grew up in the area, we were able to get a more personal view of the locality and its history.

We shall be finishing the year with a look at Quaternary Boulder beaches of SW England at the end of November, and in December a final ex BO's trip led by Linda to Meldon to look at sediments, structures and igneous rocks on the western margins of Dartmoor.

Branch membership remains at about 140 with 31 family members.

Mike Hermolle

Walton Hall

We always count our blessings at Walton Hall branch because not only do we have the use of the PRG room in the Earth Sciences department for our regular monthly meetings, but we also enjoy the company of Earth Science department members who come to our meetings, give us talks and lead field trips. So it was no surprise in January when so many turned up to hear David Jackson, the recently retired OU film producer, on "OU Stars and Shooting Rocks". It was the OU version of "Aunty's Bloomers", where David showed his favourite clips of hilarious happenings when filming the OU course videos.

February brought the AGM, and the retirement of Jenny Bennett as our Branch Organiser. So, a big thank you to Jenny for all of her hard work in the last few years – organising speakers, arranging trips and working with the committee to give us such an interesting programme. I will do my best to keep standards up! After the AGM, David Maddocks entertained us with a wonderful set of slides taken in Namibia showing the rocks and the wildlife. Also in February was our Branch dinner, where our new president Professor Bob Spicer and his wife Carol were guests.

In March, Tom Miller talked about his recent trip to Arches National Park and Monument Valley in the USA illustrated by some great pictures taken by Steve Davis, and I talked about the Tar Pits in La Brea, Los Angeles. Caroline Smith from the department taught us about the "Enigmatic Urelites" in April, and in May Richard Ghail talked about the geology of Venus. In May, Andy McMillan, of Goldpanning fame, talked to us about his PhD field work in Madagascar, and now has about a dozen willing volunteers to carry his bag next time he goes out! In September we were looking at Meteorites with Dr Norm Macleod of the Natural History Museum, and how they related to mass extinctions only when sea level rises and massive volcanic outpourings coincided. And in October Prof. Steve Self introduced us to the Tarawera volcano in New Zealand, and promised to lead a trip if we could get the interest and, judging by the reaction of the audience, I do not think that will be a problem. In November the talk on dating rocks planned with Sarah Sherlock from the department had to be cancelled as she was temporarily without a voice due to a nasty bug. Dawn Pirie, one of the PhD students recently returned from Hawaii, stepped into the breach and entertained us with tales of Huie, Loui and Dewie, three heat sensing remote monitors that she had devised and tested on the crater edge of Pu'u 'O'o, the active vent of Kilauea, Hawaii. Sarah was very disappointed, especially as she was also to demonstrate the laser probe to us – we will rearrange for the new year.

Our "evening out in the field" that usually fills the July slot was changed to a whole day's outing on the preceding Saturday, as many people were travelling to Dublin for the Symposium on our usual night. Our outing was to the Quest clay pit at Stewartby with Chris Andrews of the Bedford Museum, but first we met at the museum for a talk on the fossil finds from Stewartby with an opportunity to see some of them and explore the museum. Despite Foot and Mouth disease, we have also enjoyed a number of other field trips during the year, visiting Denbys Vineyard and Dorking Cave with Professor Dick Selley in May, the BGS (Nottingham) and the Stone Centre (Derby) in September. Then in October, Dr Dee Edwards and Prof. John Mather led us on a beautifully constructed trip around Cornwall, ably assisted by Bruce Grant of the Royal GS of Cornwall. We started in a copper mine, now used by the Camborne School of Mines, progressed through mineralisation to mineral extraction at the IMERYS china clay pits and processing works, and ended at the Eden project.

We have a number of exciting talks planned for 2002, and trips in the "cooking pot" include the Forest of Dean, gold mining in South Wales, and possibly to New Zealand in 2003.

Linda McArdell

Wessex

It is pleasing to report on another year of growth for Wessex Branch in terms of a full and varied events programme, an increase in membership and the establishment of new initiatives to maintain interest and provide value for money. Certainly our members have voted with their feet in as much as attendance at our events, ranging from introductory days and building stones walks, through to some spectacular hands-on field events, has been consistently high. Some of the new initiatives have also helped lighten the work load of individual members of the committee who continue to apply their enthusiasm and skill for the benefit of the branch as a whole, none more so than Sheila Alderman whose contribution as events organiser has again been the mainstay of our success.

Allow me to share some of our highlights, beginning with our successfully combined AGM / day of talks and displays in January. Over 40 members and additional visitors came to Wool to hear talks in the morning from Doreen Smith, Tony Cross and Alan Holliday, followed by a scrumptious hot lunch and buffet prepared by Sheila, Doreen, Debbie Tabner and Pauline Pearce. After AGM business was concluded we were treated to a stunning photographic tour of Namibia, guided by Dave Maddocks.

It was agreed at the AGM that a small amount of the branch surplus funds could be spent on purchasing a number of maps of the Dorset Coast to assist in running the S260 Introductory day, together with a small number of inexpensive hand lenses, always useful for new or aspiring members joining a trip. We have also seen the beginnings of a branch library, through the purchase of local books and guides when visiting a new area. All of these items are available for loan to the branch and general membership.

We also decided on a corporate identity for the Branch Newsletter, now called "Wessex Footnotes" with a companion logo of an ornithopod dinosaur footprint in varied rock types, which suitably sums up the diverse geology and palaeontology of our area.

Alf Tingey has continued to exploit the generosity and skill of his contributors to produce consistently full and interesting editions of Wessex Footnotes, developing his own IT skills along the way and acknowledging the assistance of Colin Morley.

The branch website continues to be edited by Chris Phillips and is a rich source of materials for displays at national and local events, including the annual Dorset Mineral and Fossil Fair held in Wimborne during August. This year our stand was manned by Linda & Colin Morley who also brought some of their own collection of fossils and geological artefacts gathered on OUGS trips. OU study materials and reports of our ventures helped to extol the merits of studying Earth Science and the supporting role played by our society.

The branch is grateful to Debbie Tabner for taking on the role of Weekend trips organiser and she quickly got into her stride by booking the Kindrogan centre for a week long trip in the summer of 2002. This post has become increasingly important for the branch in the light of recent Package Travel Regulations (PTRs) that the society is bound to comply with for all trips over 24 hours in duration, in the UK or abroad, and that offer 2 out of the 3 elements of accommodation, travel and prepared itinerary.

Peter Martin, as well as looking after our finances so well, also chipped in by organising the highly successful Isle of Wight weekend, led by Dan Pemberton from the recently opened "Dinosaur Isle" centre and Paul Newton from the IOW Geological Society. Peter's dual role in this event is in fact discouraged in the PTRs and he has now arranged a second, trips bank account and the addition of the Weekend trips organiser as a signatory. The branch is now well positioned to fully comply with the regulations intended to safeguard the interests of participants, but also to share the work load of organisers and trustees.

The committee have used Newsletter stuffing days, originally intended to reduce the work load of the editor on whom this duty used to fall solely, to discuss these and other matters relating to branch and society affairs. As we are quite widely dispersed across the region, we also make good use of email and opportunities at the field meetings to keep up to date both efficiently and economically.

Of course the biggest curtailing factor to negotiate this year was the awful Foot and Mouth outbreak. The branch was fully committed to following guidelines aimed to stop the spread of the disease and also main-

tain the integrity of the society and earth science institutions as a whole. Working closely with local authorities and MAFF instructions, thankfully only one of our events was disrupted, that to the Forest of Dean. Otherwise we were able to make the most of our varied coastal exposures, accessible quarries in non restricted areas and town centres.

Our S260 introductory day at Worbarrow was switched on the morning itself to Lulworth Cove following the closure of the Army ranges at the outset of the restrictions, put in place the night before.

An earlier trip in January to Studland & Swanage led by John Chaffey kept with tradition for the first trip of the year and was very well attended, taking in coastal geomorphology and the increased rate and size of landslips that have been a feature all along the coast this year. John also led us in the Isle of Purbeck in September for a walk from Langton to St Aldhelms Head and is set to wind up our programme by leading a visit to Hengistbury Head in November.

Venturing far and wide in the region we have also been on the geological trail on Albury Downs with Ian Fletcher, and Winchester city centre for a building stones walk with Tony Cross.

Adrian Brokenshire used his knowledge as an enthusiastic palaeontologist and Countryside warden for English Nature to show us some of his favourite sites around Portland and the Fleet shore, always good for a range of easily collectable fossils. Some of these were presented to our hosts from La Societe Guernesiaise during our Easter trip to the Channel Islands. Though quite grey and chilly, it was free from Foot and Mouth restrictions and a wonderful mix of geology and socialising was enjoyed, with thanks to Nigel Spencer from South East branch for his additional leadership.

In May we travelled to the west coast for a day looking at the lower Lias and Triassic structures on view at Blue Anchor and Kilve, with friends from South West and Severnside branches. We were led by Phil Rogers, who gently cajoled us to use our knowledge and observations to discover for ourselves the sequence of events in the geological past that make the North Somerset coast what it is today.

A hot Sunday in early August found a few of us in Ockley Brickwork's clay pit in Surrey looking for Wealden Fossils with some success, led by Peter Austen. It was nice to be involved when some particularly rare arthropod track-ways were found.

Quarries don't come much bigger than Torr Works, on the edge of the Mendips near Frome. Though the prospect of being confined to a coach tour, for health and safety reasons, may have been disappointing at first, the site is so big that it is really the only practical way of seeing it all. Guided by Peter Chapman, the public relations manager, we had a very good insight into the value of rock as a versatile physical resource and also the considerable investment made by Foster Yeoman's to conserving and indeed enhancing the local environment. Britain's one and only "walking" crusher was also on view. As a bonus Alan Holliday led us on a visit to nearby Vallis Vale to experience the classic De la Beche unconformity and included some interesting structural geology on the track to Tedbury camp.

In October Alan also led us on a joint trip with Dorset GAG to Portishead, in what was to be the worst weather conditions encountered this year. As I write another joint trip is underway, this time in brilliant sunshine at Brighton with Paul Davis of NHM taking us to some of his favourite chalk fossil collecting localities.

We are extremely grateful to all our leaders and organisers for making our pursuit of geology in the field so enjoyable. "Just wash & go " seems an apt description of how easy they make it for us, while giving so freely of their time and enthusiasm.

A society with nearly 3,000 members requires a good deal of administration of its finances, membership, publicity, sales, library, journal and newsletter publication. Many thanks to the officers of the Executive committee, who under the steady leadership of our retiring chairman, John Lamont, have served the society so diligently and expertly over the year. Particular thanks are due to the sub committee who wrestled with the PTRs to come up with workable and simplified proposals to cover our activities at home and abroad. Congratulations to the Ireland Branch for a wonderful symposium in July and to our colleagues in other branches for your success in recruiting new members at OU summer schools. Biggest thanks of all though go to our own members who have supported the branch and our various activities through the year.

George Raggett

West Midlands

This year has been one of great upheaval for the West Midlands branch, not just the disruption caused by Foot and Mouth Disease but also the loss of our branch organiser. Foot and Mouth Disease all but wiped out the branch's programme of field trips for the year with only one taking place in September.

Mid-way through the year our branch organiser had to relinquish the post because of increased family commitments. As a branch we wish her well and hope things go well in the future.

These two events combined to give the branch a very poor year but also the chance to start planning the events calendar for 2002 well in advance. It also allowed time for the branch committee to introduce some new ideas for field trips and lecture-based days.

All in all the West Midlands branch are looking forward with high hopes to an interesting 2002.

Chris Gleeson

West Scotland

The year promised much with many events arranged, including trips to St Andrews, the North West Highlands, Isle of Arran, Ballantrae, Knapdale and the Tayvallichs, Comrie and the Earthquake House, Balmaha, and the Trossachs. The last two and a visit to the Hunterian Museum in Glasgow University were the only ones which came off. Foot and Mouth disease put paid to many University Earth Science field trips including ours this year. However, as someone said " the rocks have been there for millions of years – one more won't make much difference."

The AGM in January saw Jane Hickman stepping in as Newsletter Editor and Susan Clark make a sideways shift to Branch Treasurer. Maureen van Stratum (an excellent name for a Geologist) agreed to set up our Web page and was duly appointed as Web Slave. An excellent talk by Dr Iain Allison of the Glasgow Society on the geology of the Yemen entitled 'North Sea Geology Without Getting Your Feet Wet' rounded off the day and then we all headed off for some Italian cuisine.

The Hunterian Museum day in February with Head Curator Dr Neil Clark was, as always, fascinating and we had the opportunity to visit the BBC's Walking with Dinosaurs exhibition which had arrived in Glasgow the previous week. The Scottish Dinosaur had been reincarnated and Neil gave us a run down on how the beast had been reconstructed from just two bones – I believe another bit has been discovered this year. The kids loved the challenge to race a dinosaur and, as is usual with children, they asked the most intelligent questions. We were all enthralled by the specimens Neil pulled out when we later visited the store and workshop in the afternoon. The sight of a PhD student trying to reconstruct a giant goldfish from what appeared to be a jigsaw by Escher was mesmerizing.

The advent of Foot and Mouth put paid to most of our programme from March till September when we hoped to have a trip to Comrie with Norman Butcher. Unfortunately for us – definitely not for Norman – this had to be called off. He had received an invitation to take part in a trip to Greenland with some colleagues and understandably didn't want to miss this once in a lifetime opportunity.

In February I had been invited by Neil Clark to get involved in Scottish Geology Week and have been attending the organizing committee meetings throughout the year. This event has grown from small beginnings to being the premier event in the Scottish geological calendar. This year there

were over100 events up and down the country. Professor Aubrey Manning of BBC's 'Earth Story' fame was the guest speaker and got the week off to a great start. Dr Stuart Monro told us a bit about Edinburgh Volcanics and we were then treated to a viewing of the capital's latest eruption – from a massive papier mâché cone set in the forecourt of the Centre. A plume of orange smoke, a roll, or rather a barrage, of drum music, some of the local Lava Cakes, a cup of coffee and the week had begun.

Our contribution to SGW comprised a field trip to the HBF in the Balmaha, Loch Lomond area. It was reasonably well attended and Dr John Mendum of the BGS gave us a very interesting day out. We also acted as guinea pigs for Phil Glennie of the Countryside Rangers Association on the following Saturday when he tried out his presentation to be given to another group on the Sunday. Very good he was too. We covered a good deal of the Trossachs area by minibus and rounded off the day with a stroll along an esker in the town of Callendar.

It is with deep sorrow that we announce that Lindsay Hamilton, our former Events Officer and long time member of the Society, died on October 12th after a long battle with cancer. Our sympathies go out to her husband David and her sons Ewan and Neil.

Stuart Fairley

Yorkshire

Our year started at the AGM in January with a talk from Phil Manning at the Yorkshire Museum on some research he had done on the early years of the local Philosophical Society and their interest in the natural sciences. This was followed in early February with our winter weekend in Edinburgh. David Land showed us round Arthur's seat (Edinburgh's volcano) and Holyrood Park. We then went for a historical (geology in the making!) tour of Mary Icing's Land, roads and house still remaining in the foundations of later buildings. The Sunday saw us at Dynamic Earth with Stuart Monro.

Our March visit was to York Minster's undercroft, the York glaziers' trust and the Minster stone yard. We were shown round the undercroft by someone who had worked on the underpinning below the central tower.

After this our programme was radically changed due to foot and mouth, Yorkshire being one of the hardest hit areas with restrictions continuing. Among the postponed events were: glacial and coastal features; Kettlewell in Wharfedale; the Sedgewick trail etc.; the first one of these having already been postponed from the previous year due to petrol problems. However, city stone and cemetery walks and indoor events were arranged, including the English National Mining Museum in Wakefield and the Magna Centre, only to be cancelled due to lack of interest; perhaps it is the fresh air and a picnic that entices us on the trips.

A city walk in June went ahead. Jock Marshall took us round the commercial buildings of Leeds complementing his previous walk round the civic buildings.

In July many of our members went to Dublin for an interesting symposium, in many cases staying for extra days to take advantage of the additional field trips, again unfortunately curtailed by foot and mouth.

On 10th November eight members spent a fascinating morning in the cellars of Cliffe Castle Museum in Keighley looking at their collections of geological specimens, many collected and catalogued in the 19th century.

Hopefully we can look forward to a full programme of field visits in 2002, starting with the winter weekend at Whitby.

I would like to thank all our leaders and the committee members for making this year as organiser such an enjoyable and rewarding one. I hope however, that we shall have rather more field trips in 2002.

Barbara Norton

Book review

Sedimentary Basins: Evolution, Facies and Sediment Budget by Gerhard Einsele, 2000, Springer-Verlag, 792pp, £51.50 (hardback) ISBN 354066193.

Sedimentary geology is a major part of Earth Sciences and continuing exploration for hydrocarbons has increased the importance of this discipline over the past few years. This book on sedimentary basins is a revised, updated and enlarged version of the first edition published in 1992 and has introduced quantitative aspects to sedimentary geology.

This substantial volume is essentially a textbook suitable for advanced university students and research workers. The book consists of 14 chapters which are divided into 5 parts: 1, Types of sedimentary basins; 2, Depositional systems; 3. Subsidence, Flux and Sediment Budget; 4. Basin Evolution and 5. Diagenesis and Fluid Flow. All chapters and major sections are structured in the same way with brief boxed summaries, targeted for busy or less experienced readers and for the more experienced, specific local or regional data are given in small print. Each chapter is well illustrated and in many cases, 3-D depositional systems have idealised stratigraphic logs giving sedimentary successions and facies associations. In general, each chapter has the same layout, so in principle, the book is easy to use as the format is consistent. Depositional systems covered are: Continental sediments; Coastal and shallow sea sediments (including carbonates); Sediments of adjacent seas and estuaries; Oceanic sediments; Special depositional environments and sediments e.g. red beds; and Sequences, minor cycles and event stratigraphy.

Overall Sedimentary Basins is well presented and aims to provide a broad overview of sedimentary geology but a good basic knowledge of the subject and terminology is required, especially as no glossary is provided. The approach is 'actualistic' concentrating on the processes operating in modern depositional environments, which are then used to interpret ancient sedimentary systems. Case studies are mostly taken from the younger geologic past (Mesozoic-Recent) with examples from all continents.

However, I found this book difficult to use as it is almost too extensive in its coverage of all basin types. Some sections are more comprehensive than others, for example, continental sediments are covered in greater detail than coastal and shallow sea sediments. Thus, in order to keep the book to a manageable size some important aspects are not covered in sufficient detail to be a useful addition to my bookshelf.

Jacqui Malpas BSc Hons (Open) and continuing ES student

The Age of the Earth: from 4004BC to AD2002 by C L E Lewis and S J Knell (eds), 2001, Geological Society Special Publication 190, 288 pp, £70 hardback, ISBN 1862390932.

This book contains 19 papers, some of which were presented at the Geological Society's William Smith Millennium Meeting, Celebrating the Earth, in June 2000. However, as Cherry Lewis and Simon Knell say in the Preface, this volume is not just a record of the conference; a number of the contributions were not presented at the meeting and all the papers were revised. The contributors represent the disciplines of biology, physics, astronomy, and history of science as well as geology.

The first paper, by Cherry Lewis and Simon Knell, gives an overview of the subject of dating the age of the Earth, from the belief of Zoroaster in the 6th century BC that the world had been in existence for 12,000 years to the calculation by Patterson in 1956 that the "time since the earth attained its present mass" was 4550 plus or minus 70 Ma.

It was fascinating to read about the ideas of the 18th century natural philosophers and the growing conviction of the extreme age of the Earth. Previously unknown to me and so, perhaps, even more enthralling, was to read about Jean-Andre de Luc (1727-1817) who first proposed the term geology in its modern sense and John Phillips (1800-1874) who

recognised the potential of the ideas about the temperature of the Earth's interior.

I particularly enjoyed Hugh Torrens's paper about William Smith and his significant contribution in the 19th century to unravelling relative geological time and space. Cherry Lewis's paper Arthur Holmes' vision of a geological timescale shows the immense contribution Holmes made in the 20th century to the development of the geological timescale.

In the final paper Understanding the beginning and the end, Sir Martin Rees, the Astronomer Royal, sets the Earth in a cosmic perspective and sees the challenge for the new millennium as understanding how the Big Bang produced the complex habitat in which we live. Each paper stands on its own and so one can read the book in any order although it is fascinating to follow the chronological sequence of ideas and discoveries. There is a list of References at the end of each paper and a comprehensive index at the end of the book.

This is an eminently readable book which will be enjoyed by anyone with an interest in the development of ideas and concepts of the Earth's history.

Elizabeth Maddocks BA (Open)

Climate Change: A Multidisciplinary Approach by W J Burroughs, 2001, Cambridge University Press, 298pp, £18.95 (paperback) ISBN 0521567718.

As the title suggests this book takes a multidisciplinary approach to climatic changes. It looks at how past climate was recorded in the rock record, the various methods of recording climate since man started observing it, and how current scientific knowledge can be used to predict the future.

The work opens with background information looking at radiation and the earth's energy balance and how this has effected climate over the passage of time. This is followed by information on the oceanic-atmospheric circulation patterns, the hydrological cycle, and how they interact with each other.

Evidence of past climatic change is looked at in relation to the rocks, as geologists unlock climatic clues from its stratigraphic record. Atmospheric composition, sea level fluctuation, ice ages, and twentieth century warming are all considered along with the consequences of climatic change on flora, fauna, mass extinctions, ice caps and sheets, and agriculture.

By exploiting a wide range of measurements a coherent picture of climatic change can be built up. The various methods of measurements used for this build up were assessed in terms of their reliability and value, these included instrumental observations, satellite measurements, historical records, dendrochronology, ice cores, ocean sediments, pollen records, and isotopic dating.

The book then moved on to look at physical methods that can cause climatic change. The variables considered were the atmospheric-oceanic interactions, tidal forces, volcanoes, sun spots and solar, activity, orbital variations and human activity.

The book concludes with a look at climate modelling, and the problems that climatic prediction can incur.

Each chapter concludes with a summary, several questions to let you test your understanding, and suggested further reading. The book has a good bibliography and a useful glossary.

Glynis Sanderson BSc Hons (Open), MSc

Sedimentary Petrology by Maurice E Tucker, Third edition, 2001, Blackwell Science, 262 pp, £28.50 paperback, ISBN 0632057351.

This publication will be known to many as the definitive text on sedimentary geology. No doubt those of you who studied the now discontinued course, S338, Sedimentary Processes and Basin Analysis will remember "Tucker" as the essential reference book. At that time I used Volume 3, which I found somewhat daunting initially because of the huge amount of information it contains. However, I have since developed a great affection for it and have referred back to it ever since.

The book deals systematically with each sedimentary rock type. The introduction outlines the basic concepts and methodology which is applied to the subsequent chapters. Each chapter then details the composition, textures, structure, origins and diagenesis of specific rocks; leading to an understanding of their facies geometry and porosity evolution.

This book seeks to provide an understanding of the deposition and evolution of sedimentary rocks, but does not cover the concept of sequence stratigraphy. The author feels that the essential facts presented here are the foundation on which to build knowledge of depositional environments and facies of sediments.

I now have in front of me the Third Edition. This follows the same format as previous volumes but has been updated and expanded in text and figures throughout. It has a new double-column format which makes it easier to read. New tables have been included, eg for the identification of rocks in hand specimen, and a scheme for describing sandstones in thin section. New photographs of examples are also added.

Sedimentary Petrology is indisputably an essential reference book for every student of sedimentary geology. It surely earns its place on the shelf!

Ellinor Morgan, BSc Hons (Open)

Biotic Responses to Global Change: The last 145 Million Years edited by S J Culver and P F Rawson, 2000, Cambridge University Press, 501pp, £60 (hardback) ISBN 0521663040.

A big booming bass-filled book, hardback, weighty tome that says it all in its title. A long term view is taken. And to accomplish this requires a veritable weight of detail to be expounded. This book provides such detail in pages upon pages of tight text. Though there is a dearth of images to enliven the dense text. The beauty of this book is in its detail; covering the major taxa and the effects of global change upon their evolutionary development. The time period covered is from the Cretaceous to the present.

The style of writing is not inaccessible, however the books target audience is "researchers and graduate students in palaeontology, geology, biology, oceanography and climatology". This requires the use of very detailed scientific language which may engender some fear into readers outside the target audience i.e. the enthusiastic non-specialist. I found some of the diagrams not particularly helpful, though the cladograms were insightful. More reconstructions of the past and visually how changes affected biota would have given the text more zip.

The book should be more accessible to a wider audience as the message of climate change affects us all. For are we not biota? If as Earth Science professes it has a vast data bank of knowledge that gives us a broader and more realistic view of climate change, 145 MA is no small database: A wider audience needs to be exposed to this research and ideas to develop their understanding of the issues. The main drawback to the book is to understand it fully, the reader needs prior knowledge of the subject areas.

The book would provide a very useful addition to the reading list of students studying S369. In reality it is a reference tome for use in research. If you want it, then be prepared to pay £60. And be prepared for a taxing read, but worthwhile one for all that.

Ivan Finney BSc Geology (Dunelm),
MSc Sedimentology (Reading),
Open University Associate Lecturer:
S102, S236, S338 and presently S260 and S369.

THE CONSTITUTION OF THE OPEN UNIVERSITY GEOLOGICAL SOCIETY

1 NAME

1.1 The Society shall be known as the Open University Geological Society (OUGS) herein after referred to as The Society.

2 AIM

2.1 To promote and advance public education in the field of geology and other earth sciences. In furtherance of that object but not further or otherwise The Society shall have the power to do all or any of the following:-
(i) Promote and support local branches of The Society.
(ii) Organise symposia, conferences, national and local events.
(iii) Provide a means by which members receive information on the activities of The Society and on earth sciences.
(iv) Foster good relations with organisations having related interests.
(v) Raise funds.

3 MEMBERSHIP

3.1 Full Membership shall be open to:
i) past and present students of The Open University.
ii) academic, research, technical, tutorial and counselling, and administrative staff of The Open University.

3.2 Associate Membership shall be open to any adult person (i.e. aged sixteen or over).

3.3 Family Membership shall be open to any other named adult residing at the same address as a full member.

3.4 Temporary Membership shall be open to any adult person and shall be valid only for the duration of the event in which the temporary member is participating.

3.5 Joint membership shall be open to two full members residing at the same address at an appropriate subscription.

3.6 A member in any of the above categories shall be defined as one who has paid a current and appropriate fee.

3.7 The President and Past Presidents shall be deemed members for life of The Society and shall not be required to pay any subscription.

3.8 Honorary Life Membership may be conferred by a general meeting of The Society following recommendation by the OUGS Committee, to which body ordinary members may make recommendation.

4 SUBSCRIPTIONS AND FINANCE

4.1 The Society's year shall run from 1st January to 31st December.

4.2 The annual subscription and temporary membership fees shall be decided at the preceding Annual General Meeting. The annual subscription shall become due on the first day of the Society's year.

4.3 Subscriptions received from members joining for the first time on or after 1st July will extend over that year and the whole of the following year.

4.4 If a subscription has not been renewed by 31st March, membership shall be deemed to have lapsed.

4.5 Any member acting on behalf of The Society shall keep a record of income and expenditure incurred.

4.6 The accounts of The Society shall be subject to annual audit. Audited annual accounts shall be presented by the OUGS Treasurer to the OUGS Committee, to the Open University Students Association (OUSA) and to the next Annual General Meeting of the Society. Copies of the audited accounts shall be distributed to members not later than one month before the Annual General Meeting.
A member may request a copy of the accounts after audit has been announced in the OUGS Newsletter.
The auditor(s) for the next financial year shall be appointed at the Annual General Meeting.

4.7 The OUGS Treasurer shall present a statement to the Annual General Meeting on the current financial situation of The Society and a forecast for the coming year.

4.8 Fund raising shall be subject to the approval of the OUGS Committee.

4.9 Any university, library, organisation or society may receive any publication of The Society by payment of a fee equivalent to the current membership fee or in exchange for some similar publication.

4.10 Members of The Society may be reimbursed for any expenses incurred on behalf of The Society, but shall receive no fee.

5 GOVERNMENT

5.1 The OUGS Executive shall be responsible for the management of The Society.
The OUGS Committee shall be responsible for overall policy and for the activities of The Society's Branches.
Members of the OUGS Committee may act individually or collectively to deal with routine matters.

5.2 The OUGS Executive shall consist of the following:-
The President
The Chairman
The Secretary
The Treasurer
The Membership Secretary
The Newsletter Editor
The Information Officer
The Events Officer
plus a Branch Organiser (elected annually in June by the Branch Organisers).

5.3 (i) The OUGS Committee shall consist of the following:-
The members of the OUGS Executive
The Branch Organisers
The Sales Officer
All members of the OUGS Committee must be Full Members of The Society at the time of their election and for the duration of their term of office.
At least one member of the OUGS Committee shall be a current student of the Open University.
(ii) The Society's Representative or Deputy Representative to OUSA shall be entitled to attend meetings of the OUGS Committee, but shall not have voting rights at such meetings.

5.4 The OUGS Executive may co-opt the following post-holders:-
- a Minutes Secretary for each national meeting
- a Journal Editor
- an Administrative Assistant
- a Gift Aid Secretary
- the Symposium Organiser(s)
- such other assistants as may prove necessary

These post-holders may attend OUGS Executive and OUGS Committee meetings as appropriate, but shall not have voting rights at such meetings.

5.5 (i) No one person shall hold two or more posts on the OUGS Committee concurrently.
(ii) No one person shall hold two or more posts on the OUGS Executive consecutively. Election to the position of Chairman of The Society shall be an exception.

5.6 The OUGS Committee shall invite a member of the academic staff of the Earth Sciences Department of the Open University to be President of the Society for a term of two years, commencing in even-numbered years.

5.7 The Society through its OUGS Committee shall be empowered in exceptional circumstances to offer a position of Vice-President.

6 PROCEDURE

6.1 There shall be an Annual General Meeting (AGM).

6.2 A Special General Meeting may be called at the request of the OUGS Committee, any three branches, or fifty full members. The motion(s) to be debated at the meeting must be specified in writing at the time the request is submitted to the OUGS Secretary.

6.3 General Meetings shall be conducted according to the Standing Orders for General Meetings.

6.4 The OUGS Secretary shall give fourteen weeks notice in writing to all members of the date, time and venue of any OUGS General Meeting. OUGS General Meetings shall be held at weekends or on public holidays.

6.5 (i) Any member shall give the OUGS Secretary at least twelve weeks written notice of any constitutional motion to be placed on the agenda of the Annual General Meeting.
(ii) Any member shall give the OUGS Secretary at least four weeks notice of any non-constitutional motion to be placed on the agenda of the Annual General Meeting.
(iii) Other matters may be placed on the agenda of any OUGS General Meeting subject to the approval of the OUGS Executive.

6.6 The OUGS Secretary shall send the agenda for OUGS General Meetings to all members at least two weeks before the meeting.

6.7 Nomination for election as Officers of The Society should reach the OUGS Secretary at least two weeks before the appropriate AGM. Nominations shall be in writing, with written permission of the nominee and endorsed by two Full Members of The Society.

6.8 Membership of The Society must be proved to gain entry to General Meetings.

6.9 Full Members may speak on motions at General Meetings and may vote. Associate and Family Members may speak on motions at General Meetings but may not vote.

6.10 Members of the OUGS Committee shall submit their resignations at the appropriate AGM, but may be eligible for re-election.

6.11 (i) OUGS Committee Members other than Branch Organisers shall serve for a term of two years, with a maximum of six years and six months in the same post.
(ii) OUGS Committee Members other than The President and The

Chairman shall be elected at the appropriate AGM.
(iii) The Society's Representative and Deputy Representative to OUSA shall be elected at the appropriate Annual General Meeting, each to serve for a term of two years.

6.12 The Secretary, the Membership Secretary, the Information Officer and the Society's Representative to OUSA shall be elected at the Annual General Meeting in even-numbered years.
The Treasurer, the Newsletter Editor, the Events Officer, the Sales Officer and the Deputy Representative to OUSA shall be elected at the Annual General Meeting in odd-numbered years.
Individual elections to be in the order given above.

6.13 (i) The Chairman of The Society shall be elected by the OUGS Committee from amongst members who have served on the OUGS Committee for a term of office during the previous five years. The election shall take place in odd-numbered years.
(ii) Nominations for the post of Chairman of The Society shall be made in writing by members of the OUGS Committee, to the OUGS Secretary at least two weeks before the meeting of the OUGS Committee at which the election of the Chairman is to be held.
(iii) When a vacancy occurs by resignation, disqualification or death of the Chairman of The Society, a new Chairman shall be elected at the next OUGS Committee Meeting, pending which the OUGS Secretary shall assume the responsibilities of the Chairman.

6.14 Members of the OUGS Committee, other than the President, the Chairman and Branch Organisers, shall be elected by single transferable vote of Full Members present at a General Meeting of The Society.

6.15 When a vacancy occurs by reason of resignation, disqualification or death a replacement shall be appointed by the OUGS Executive to fill the vacancy until the next General Meeting, when the replacement shall retire, but may stand for election for the next or remaining term of office.

6.16 The Society's Constitution may only be amended at the OUGS Annual General Meeting or at a Special General Meeting called for the purpose. A two-thirds majority of those present and voting is required for such amendments. No alteration may be made to the Constitution(s) which would cause the Society to cease to be a Charity at Law.

6.17 All other voting decisions shall be by simple majority.

6.18 The Society may be dissolved by consent of two-thirds of those present and voting at a Special General Meeting called for that purpose. If upon winding up there remains after the satisfaction of all debts and liabilities any funds whatsoever the same shall not be paid or distributed amongst the Members of the Society but transferred to some other society or societies having objects similar to those of The Society and if and so far as effect cannot be given such provision then to some charitable object, that shall include OUSET (Open University Students Educational Trust).

7 BUSINESS

7.1 The OUGS Committee shall meet at least twice a year, once immediately before the AGM.

7.2 A quorum of eight, five of whom must be Branch Organisers, shall be required at a OUGS Committee Meeting with at least one of the following present: Chairman, Secretary or Treasurer. A quorum of four shall be required for a OUGS Executive Meeting with at least one of the following, Chairman, Secretary or Treasurer.

7.3 The OUGS Committee shall be empowered to appoint Special Committees whose objectives and reporting dates shall be defined in writing by the OUGS Committee. All members of The Society shall be informed of the formation and objectives of any such committee at least fourteen days before the reporting date.

7.4 Minutes shall be taken of all OUGS Executive and OUGS Committee Meetings and copies circulated to OUGS Committee Members.

7.5 The minutes of any OUGS General Meeting shall be published in the next possible national newsletter of The Society after the meeting to which they refer.

7.6 The OUGS Committee shall maintain Guidelines for the operation of The Society. Such Guidelines shall be available to members of The Society.

8 LIMITATIONS

8.1 The name or any logo of The Society may not be used without the permission of the OUGS Executive.

8.2 The Society cannot accept liability for the costs of any damages, fire, theft, legal fees or injury incurred by the activities of individual members.

8.3 The OUGS Committee shall have the right to suspend or expel any Officer, OUGS Committee Member, Full, Associate or Family Member acting against the aims of the Society after full consideration of the case. The member shall have the right to present a case, or a subsequent appeal, to the Committee either orally or in writing. The case or appeal may be presented by any person of the member's choice. Any member so treated shall have the right to appeal to The Society at the AGM following.

8.4 The OUGS Committee reserves the right to refuse admission to any applicant for membership who they have reason to believe is unsympathetic to any of the aims of The Society or the interests of its members or is liable to bring The Society's good name into disrepute. Any such person refused membership shall have the right to make representation orally and/or in writing and to be represented by any other person of their choice. Anyone refused membership by the OUGS Committee may appeal against the decision to the President of The Society.

9 INTERPRETATION

9.1 Any matter of doubtful interpretation, or not provided for in the Constitution shall be dealt with by The OUGS Executive pending endorsement or otherwise at the next General Meeting.

As amended at the AGM of the Society 17 November 2001.

BRANCH CONSTITUTION

This Branch Constitution will be used in conjunction with the Constitution of the Open University Geological Society

1 NAME

1.1 The Organisation shall be called the ..... Branch of the Open University Geological Society.

2 AIMS

2.1 (i) To further the objects of The Society in advancing education.
(ii) To provide a local means for forwarding the aim of the Society.

3 MEMBERSHIP

3.1 Membership shall be open to all members of The Society who are best served by the ..... Branch, or who have chosen to be allocated to that Branch.

4 FINANCE

4.1 Any Branch Member shall ensure a record is kept of any monies expended or received on behalf of the Branch.

4.2 The Branch Treasurer shall present audited accounts to the Branch AGM. A copy of these accounts must be sent to the OUGS Treasurer within four weeks of audit.

4.3 The Branch shall have the power to raise funds from any sources approved by the OUGS Executive.

5 GOVERNMENT

5.1 The Committee shall consist of:-
- the Branch Organiser
- the Branch Treasurer
- other Committee Members, one or more, as required

5.2 The Branch Organiser, the Branch Treasurer and at least one other Committee Member must be Full members of The Society at the time of their election and for the duration of their term of office.

5.3 (i) No member shall hold any other post on the OUGS Committee at the same time as that of Branch Organiser.
(ii) No member shall hold the post of Branch Treasurer at the same time as that of OUGS Treasurer.

5.4 The Branch Organiser shall represent the Branch at The OUGS Committee or, if absent, must nominate a Branch Committee member as deputy who shall not otherwise be a member of the OUGS Committee.

6 PROCEDURE

6.1 There shall be a Branch Annual General Meeting. Minutes must be kept and a copy sent to the OUGS Secretary and the OUGS Treasurer within four weeks. (NB Branch Grants may not be paid if this and 4.2 are not complied with).

6.2 Branch General Meetings shall be conducted in accordance with Standing Orders for General Meetings Addenda 1.

6.3 The Branch Organiser shall ensure a minimum of four weeks notice in writing is given to Branch Members and the OUGS Secretary of the date and time and venue of the Branch AGM.

6.4 All members of the Branch Committee shall retire at the Branch AGM but be eligible for re-election.

6.5 A special Branch General Meeting may be called at the request of 10% of the members, or five members, whichever is the greater, or by the Branch Committee or by the Branch Organiser.

6.6 Within two weeks of receipt of notice of a request for a Special Branch General Meeting, the Branch Organiser shall give not less than three and not more than five weeks notice in writing of the agenda to all Branch Members, and to the OUGS Secretary, giving the date, time and venue of the meeting.

6.7 Every field trip, lecture or other gathering shall be considered a Branch Meeting.

6.8 In the absence of the Branch Organiser, a Chairman shall be elected from

among the members present at a Branch Meeting if business is to be conducted formally.

6.9 A Branch Constitution may only be amended with the approval of the OUGS Committee before being amended formally at the next General Meeting of the Society. No alteration may be made to the Branch Constitution which would cause The Society to cease to be a Charity at law.

DISSOLUTION CLAUSE

If upon dissolution there remains after satisfaction of all debts and liabilities any assets whatsoever the same shall be given to the Open University Geological Society or if that body has already been dissolved then to some charitable object which shall include OUSET.

As amended at the AGM of The Society 17 November 2001.

STANDING ORDERS FOR GENERAL MEETINGS OF THE OPEN UNIVERSITY GEOLOGICAL SOCIETY

1 QUORUM

a) A quorum of twenty five Full Members shall be required of whom at least ten shall not be OUGS Committee members.
b) If a quorum is not present within one hour after the time appointed for the meeting to commence, the meeting shall be dissolved.

2 AGENDA

a) The agenda shall be prepared by the Chairman and the OUGS Secretary.
b) Items not on the agenda may be introduced for consideration after business on the agenda has been completed.

3 THE CHAIR

a) The Chairman of The Society shall take the Chair.
b) If the Chairman is absent the President of The Society or another member of the OUGS Executive shall deputise.
c) The Chairman shall be responsible for the conduct of the meeting.
d) All business shall be addressed to the Chair.
e) Should the Chairman wish to participate in a debate, the Chair shall be surrendered to the President or other agreed deputy for the duration of that debate. The person occupying the Chair may not participate in any debate.
f) The Chairman may call attention to irrelevance, repetition, unbecoming languague or any breach of order on the part of a member, and may direct the member to discontinue. In the event of persistent disregard for the authority of the Chair, the member shall retire for the remainder of the meeting.
g) The Chairman's decision on the interpretation of the Standing Orders, and on any point of order not provided for by the Standing Orders, shall be final.

4 RULES OF DEBATE

a) The Chairman shall decide the right of priority in speaking.
b) No speech shall occupy more than three minutes without the consent of the meeting.
c) A motion or amendment shall be proposed and seconded by a full member.
d) The proposer shall have first speech, after which the motion or amendment shall be open for debate.
e) No member except the proposer may address the meeting more than once on any one motion.
f) Once open for discussion a motion may only be withdrawn with the consent of the meeting.
g) The proposer of the motion shall have the right to sum up on the debate immediately before the vote is taken. The proposer may waive the right absolutely or in favour of another person.
h) No new information shall be introduced after the summing up has begun.
i) There shall be only one motion or amendment before the meeting at any one time.
j) Amendments to any matter on the agenda may be accepted up to the commencement of the meeting, subject to (c) above, or at the discretion of the Chairman.
k) No member may move more than one amendment to any motion.

5 VOTING

a) Each Full Member present excluding the Chairman shall have one vote.
b) The Chairman shall have a casting vote in the event of a tie.
c) Except for elections, voting shall be by a show of hands unless five Full Members request a ballot.
d) For a motion to succeed, a simple majority shall be required, except that any motion to amend the Constitution, Branch Constitution or Standing Orders shall require a two-thirds majority.

6 ELECTIONS

a) The system of the Single Transferable Vote for the election of members of the OUGS Executive and the OUGS Committee is defined as follows:-

(i) All electors shall mark their ballot papers with their ordered preferences for the allocation of their vote to one or more candidates.
(ii) On the first count candidates shall be allocated the first preference votes on the ballot papers.
(iii) At each count the votes allocated to each remaining candidate shall be counted.
(iv) After each count the candidate allocated the least num ber of votes shall be eliminated from the election. The votes cast for the eliminated candidate shall be re-allocated to the remaining candidates according to the next preferences marked on the ballot papers.
(v) The counts shall cease when the total votes allocated to one candidate constitute an absolute majority of the total votes cast. The candidate with the absolute majority shall be declared elected.

7 PROCEDURAL MOTIONS

a) Procedural motions shall have a proposer and seconder.
b) Procedural motions shall not be proposed while a member is speaking on a point of order or information or during the taking of a vote.
c) The following Procedural motions may be put to the meeting without discussion:-

- that the motion be now put
- that the motion be not put
- that the motion or amendment be voted on in parts
- that Standing Orders be suspended (which requires a two-thirds majority)
- that the meeting be closed

d) The following Procedural Motions may be put with only one speech for and one against:-

- that the matter lie on the table
- that the matter be referred to the OUGS Executive
- that the matter be referred to the OUGS Committee
- that the matter be referred to a Special Committee for investigation or re-examination
- that the meeting be adjourned temporarily
- a challenge to the Chairman's ruling (which shall require a two thirds majority)

8 GENERAL RULES

a) No question once decided may be re-opened at the same meeting.
b) Any suspension of the Standing Orders shall only apply for the duration of the matter under discussion.
c) If an amendment is accepted by the proposer of the motion then the motion remains with the proposer. If it is not accepted by the proposer, but is then carried, the amended motion becomes the property of the proposer of the amendment.
d) Amendments tabled second and subsequent to a motion may fall if the first amendment is carried or accepted. The Chairman shall rule on this.
e) Points of information may be raised by any member.
f) Points of order may be raised by any member. They have precedence over all other business except the taking of a vote unless they concern the conduct of the vote. They must be framed as a question to the Chairman and shall be related only to the conduct of the meeting.

ADDENDA 1

1 These Standing Orders shall apply to Branch Meetings of the Open University Geological Society.

2 Branch General Meetings shall be conducted according to Standing Orders for General Meetings, subject to the following amendments:-
i) 1(a) shall be replaced by "*A quorum of 5% of the Branch members or five members, whichever is the greater, shall be required.*"
ii) 2(a) shall be replaced by "*The agenda shall be prepared by the Branch Organiser.*"
iii) 3(a) shall be replaced by "*The Branch Organiser shall take the Chair.*"
iv) 3(b) shall be replaced by "*If the Branch Organiser is absent another member of the Branch Committee shall deputise as Chairman*."
v) 3(e) Delete "*the President or other*" and replace with "*an*"
vi) 5(c) Delete "*Except for elections*"
vii) 5(d) Delete "*Constitution,*" and "*or Standing Orders*"
viii) 7(d) Add "*that the matter be referred to the Branch Committee when the meeting in question is a Branch General Meeting*"

As amended at the AGM of The Society 17 November 2001.